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Autor práce: **B.Sc. Mohamed Abo Romia**
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Business Intelligence Integration in Multinational Corporate Data Structure Management

Master thesis

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Study branch:	6208T085 – Business Administration
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1. Setting research objectives and formulation of research queries.
2. Definition of target goals, tools and methods for system requirement analysis and design.
3. Collecting feedback regarding the crucial system entities, actors and data processing.
4. Analysis of current system and implementation of selected processes in the company.
5. Graphical representation of the current and the future process execution as well as the target data model.
6. Formulation of conclusions and research evaluation.

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Anotace

Diplomová práce zkoumá možnosti vývoje systému datového skladu pro účely řízení konstrukčních nákladů pomocí dat. Hlavním cílem je navrhnout systém datového skladu pro různé typy a dimenze dat s cílem zlepšit celkové podnikové procesy. Rešerše rozpracovává současnou literaturu a vývoj funkcí business intelligence. V aplikační části jsou data související s konstrukčními náklady charakterizována, strukturována a standardizována v návrhu databáze do koncepčních a logických fází. Data jsou poté nahrána do DBMS a jsou vypočteny agregátní funkce. Proces uvnitř společnosti je srovnán v podobě před a po zavedení databáze. Pomocí kvantitativních metod jsou vypočteny celkové přínosy zavedení databáze.

Klíčová slova

Business Intelligence, Regionální databáze, Hvězdicové schéma, Schéma sněhové vločky Online Analytical Processing (OLAP), Prvotní odhad a analýza nákladů, Building Information Modelling (BIM)

Annotation

This diploma thesis researches the options for developing a data warehouse system for the function of construction cost data management. The primary objective is to design a data warehouse system for different data types and dimensions with the aim of improving the company overall business processes. The study elaborates the current literature and development of business intelligence functions. Data related to construction costs is characterized, structured and normalized in the conceptual and logical phases of the database design. Data is then loaded into the DBMS and aggregate functions are calculated. The process inside the company is compared before and after the database introduction and quantitative methods are used to calculate the overall benefit.

Keywords

Business Intelligence, Relational database, Star Schema, Snowflake Schema, Online Analytical Processing (OLAP), Elemental Cost Estimation and Analysis, Building Information Modelling (BIM)

Preface

With the operational growth of companies' business and rapid changes in market data structures, there is a challenge of efficiently managing and analyzing diverse data sets across a wide array of functions, departments and operations. As the portfolio of the company grows, the data set is more extensive and in most cases is regularly updated due to market activities, events or conditions. Efficient transformation of this data into information with a value preposition enables business leverage through company insights into own as well as market-wide data, it is also an added value in the value chain of the company, representing a crucial step for success in the market. Construction management firms have a vital need for utilizing business intelligence as labor costs are steadily on the rise and construction market demand is currently soaring at its peak. Cost management of the construction process is a complicated business function, due to the nature of the construction process especially when design is not completed at the time of contract signature. Proper management of cost data is a crucial success factor for an efficient construction management practice.

This thesis objective is the research and study of the most suitable design for creating a database system according to pilot project data, to structure construction costs data and allow for advanced queries, forms, and reports to enable data extraction, easing data manipulation and transformation into a business intelligence value-added system for the company.

I would like to express the deepest of thanks and gratitude to Dr. Athanasios Podaras for his time, guidance and materials provided in support of this thesis.

Mohamed Abo Romia

Liberec,

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List of Abbreviations and Symbols

BOQ – Bill of Quantities

BPMN – Business Process Model and Notation

CSV – Comma Separated Values

DBMS – Database Management System

DWGs – Drawings

ETL – Extraction, Transformation and loading

GFA – Gross Floor Area

GIS – Geographical Information Systems

NRM – New Rules of measurement

SQL – Structured Query Language

RICS – Royal Institute of Chartered Surveyors

Introduction

This study is part of a diploma thesis oriented to assess the application of business intelligence methodologies to design a physical data structure according to the operational requirements of a construction consultancy company. The company main function is provision of cost, project and quality management services in the construction industry within Czech Republic and central Europe. The company is part of a multinational practice of construction management. The study follows the current state-of-the-art in business intelligence theories and solutions applicable to the case and aspires to improve the current process of cost report preparation in the company. The study also aims at automating the analysis and benchmarking of construction costs.

The study consists of two parts; theoretical overview and practical application. The theoretical section of this study reviews previous theories concluded in the domain of business intelligence, Data warehouse design, Data warehouse schemas and analyses each of these concepts. It discusses and elaborates the primary data structures and hierarchies used within the construction cost management domain.

The practical application builds on the theoretical section. It sets the methodology for collection of user requirements and analysis of work-flow processes, adapting the design methods to the practical requirements. It also analyses the structure of the data provided by the company for testing of the Data warehouse solution and proposes the best model to denote the data structural hierarchy. The practical part expands based on the analysis, it describes the phases of data warehouse design according to the data structure and function. Moreover, it elaborates and analyses a specific process within the company which can be improved.

In the practical part the implementation of the design method proposed is illustrated, and the Data warehouse schema design is elaborated. Also, the methods used for data extraction, transformation and loading (ETL) are described. Additionally, the functions of the Data warehouse utilization are presented, and future possible improvements are elaborated.

Background

The increasing importance of well structured, valuable data is a crucial requirement of all industries. The choice of this research topic stems from the business need within the company to improve the efficiency of the cost reports preparation and for efficient data management to improve overall performance and eliminate errors. The basic goal of this study is the creation of a business intelligence added value for the company. The impact of the Data warehouse and further use of extracted market intelligence is assumed to have an intensive effect on the business stance of the company.

The value of construction management consultancies is determined by the accuracy of the cost estimates issued as well as the efficiency and adequacy of the preparation process. The proposed Data warehouse solution has a potential of reducing delays and back-logs caused by the need to wait for experienced senior team members to estimate costs based on their know-how and expertise. Utilization of the Data warehouse is also targeted at decreasing errors that occur in cost reports due to the use of spreadsheets in managing complex hierarchal cost estimates of construction items. The Data warehouse proposed would also potentially bridge the gap between the current practices within the company from a side and Building Information Modelling (BIM) and Geographical Information System (GIS) as developments adopted within the construction industry on the other side.

In the theoretic part of study to follow, two previous contributions to the topic of adapting business intelligence to construction cost management are reviewed and analysed, this study attempts at building upon their findings and following their guidelines.

Motivation and Problem Statement

Currently, the construction cost data in the company is managed through primary methods based either on spreadsheet technology without the use of Business intelligence solutions or on personal experience, which causes deficiencies in the business process. With the current tools, and the limitations of the junior employees' experience, they cannot produce cost reports individually or with minimal supervision. The senior team members have the know-how necessary for estimation of costs from their previous experiences and market exposure. The current process of the cost report production relies on senior staff to create estimates of costs. This requirement impacts the capacity of seniors to perform other necessary functions.

Additionally, the company top-management aim at improving the efficiency of tracking cost trends over time, especially considering the current trend of inflation increase. Currently, to produce market benchmarks and trend analysis reports top-management allocate a significant portion of employee time and effort, which increases the overall company overheads. The application of a data warehouse model is introduced to reach possible improvement to the internal company processes and efficiency of workflow while decreasing errors resulting from outdated or irrelevant data used. Finally, the proposed model aims improve top-management decision support by automating the creation of analytical reports. The company management is planning to implement the Data warehouse in beta mode within this calendar year, after a review of the results and possibilities of the pilot database

This study introduces the background and basic definitions of data, business intelligence, database, and Data warehouse systems in addition to functional aspects of different types of database models and schemas. The study emphasises the tools for collection of user requirements and designs the data collection procedures. The findings from the requirement collections are analysed separately, and matches are made between functional requirements according to the priorities of user groups, functional criteria and characteristics of different Data warehouse models. The most suitable alternatives are emphasized, and the best option is presented as the proposed conceptual design. Furthermore, the analysis of the design solution and improvement in business specific workflow processes is measured using Business Process Model and Notation (BPMN) diagrams. (OMG, 2013)

Study Objectives

This study defines and examines business intelligence solutions utilized in Data warehouse design of hierarchically structured data and their schemas. The data is extracted from company historical projects selected to be the pilot projects incorporated in the Data warehouse. Additionally, the extracted data is mapped according to the standards of elemental cost analysis. Logical classification methods are followed to determine the true nature of relationships among the pilot data to further process the design and define the relations conceptually. Parallelly, this research analyses the user requirements, according to different user groups' viewpoints through a set of meetings, and questionnaires. Conclusions of the requirements analysis indicate the key criteria for the Data warehouse functionality and set the base for the design of the system adopted. Furthermore, the study identifies the available database management systems satisfying the basic user requirements.

The primary objective of this study is to research, design and implement the best possible model for a Data warehouse design to improve the efficiency of the cost report preparation process in the company.

The secondary objective of this diploma thesis is to utilise the database in calculating aggregate cost functions for the benchmarking and projection of construction work items cost estimates by functional units and area; a key parameter in construction costs estimation.

Scope of The Study

This study presents the evolution of business intelligence, Data warehouse models currently implemented and characterizes the entity-relationship data model. The formal scope of this study is to design and implement a physical Data warehouse using data from five historical construction projects as the pilot data in the Data warehouse. Mapping is used to reorganise the classification of the pilot data. The data model is designed conceptually depicting the relationships. Further processing of the data in the logical model and eventually creating the physical Data warehouse. Finally, the pilot data is loaded into the database management system DBMS and aggregate cost functions are computed. Queries are performed on the data to obtain a parametric elemental cost variables per functional units and area of the projects.

Impact of The Study

The output of this study is a functional database that enables the junior employees to make estimations of construction costs based on historical data stored in the database. This functional improvement of employee roles at a junior organizational level creates an increase in the qualitative value of employee output; both junior and senior by releasing the pressure of performing the cost estimation from the seniors, which in turn shifts their efforts towards more complex tasks in the company's portfolio. An improvement in the quality of output is targeted by the Data warehouse system as computational errors from use of spreadsheets would be mitigated. The process improvement is depicted by Business process Model Notation (BPMN) diagrams. The application of the Data warehouse to computation of market benchmarks and trends adds to the company value preposition by rendering powerful analytical tools which strategically place the company at a market advantage.

Structure of The Study

The study is structured in Six chapters, with the following sequence and contents;

The first chapter presents the introduction, background, motivation, problem statement, scope as well as the impact and structure of the study.

In the second chapter basic definitions and a literature review of studies conducted in the domain of business intelligence applications, Data warehouse design and data warehouses are presented.

The third chapter elaborates the basic principles in construction costs management and provides an overview of the construction costs classification systems, emphasising the hierarchical relationships of construction items.

The fourth Chapter tackles the Data warehouse design methodology; requirements selection, phases of the design, depicting the schemas in each phase, the physical database design and utilization for calculation of aggregate functions and extraction of data for further pivot analysis.

The fifth Chapter discusses the study results, highlights the outputs of the study, and reflects on methods utilized.

The sixth and final chapter of this study draws conclusions and recommendations for further research.

2. Business Intelligence: A Literary Review

This chapter provides an overview of available literary works on the domain of business intelligence, database management systems, Data warehouse and data models. The literary review consists of the following sections;

- Business intelligence overview,
- Background of database management systems (DBMS),
- The characteristics of database management systems (DBMS),
- Data models,
- The Object-oriented Database Management System (DBMS),
- The Entity-relationship Model,
- Entity-relationship database models,
- Data normalization,
- Hierarchies,
- Data warehouse functions and OLAP
- The design process of data models

2.1 Business Intelligence Overview

Business intelligence (BI) can be generally described as the art of acquiring the business advantage from data. According to; Muntaen, (2012) BI is an auxiliary function necessary to the success of organizations in data transformation into knowledge. (Vaisman and Zimányi, 2011) denote that business intelligence involves the set of methods, practices, tools and architecture that transform data from raw state to useful and meaningful information for decision making process. (Romney & Steinbart, 2018) introduce a much more concise and general definition of business intelligence as the analysis of large amounts of data for strategic decision making. There are two main techniques used in business intelligence: online analytical processing (OLAP) and data mining.

According to; Brijs (2013, p.6) "*business intelligence is a broad category of applications and technologies for gathering, storing, analysing, and providing access to data to help enterprise users make better business decisions. BI applications include the activities of decision support systems, query and reporting, online analytical processing (OLAP), statistical analysis, forecasting, and data mining.*"

2.2 Background of Database Management Systems (DBMS)

Before the development of Relational or Hierarchical databases, the file-based system was used for data management. Information Management System (IMS) was developed by IBM and North American Airlines and was based on hierarchical data model, later General Electric developed Integrated Data Systems (IDS) on the basis of network data model, which was developed to depict complex data relationships that could not have been otherwise handled by hierarchical structure systems. The database task group (DBTG) standardized the languages used in database management systems into three main languages data definition language (DDL), DDL sub-schema which enabled schema definition which rendered database management systems access to datasets. (Sumathi and Esakkirjan, 2007)

Business intelligence domain is a product of advancements in data related practices since as back as the 1960s, it has developed practically in form of database management systems before its theoretical developments caught up later. Early database management systems suffered shortcomings in the form of the intermixing of conceptual relationships with the physical storage, placement of records on disk and providing only programming language interface. (Elmasri and Navathi ,2011) The theoretical foundation at the time, as the practice of database management was ahead of theoretical review at the time, save for a paper published by E. F Codd titled “Relational Model of Data for Large Shared Data Banks”, this paper influenced IBM to develop and release system R project, which was developed to prove that relational data model was implementable. The outcome of system R project was the development of structured query language (SQL) which is to date the standard language for DBMS as it is an ISO standard. (Sumathi and Esakkirjan, 2007)

Nowadays, there are two DBMS models widely used, being the Object-Oriented DBMS (OODBMS) and Object-Relational DBMS (ORDBMS). With the advancements of storage and networking, relational databases became the dominant type of database systems used for traditional applications. (Elmasri and Navathi ,2011).

2.3 The Characteristics of Database Management Systems (DBMS)

According to; Connolly and Begg, (2010) DBMS are defined by support of; Data modelling; describing data, inter-data relationships and constraints. Data Persistence; the ability of data to outlive the execution or even lifetime of the program itself, which renders migration of data a crucial function of a DBMS. Data sharing; possibility of accessing data through multiple interfaces simultaneously. Reliability; Data protection from system failures. Scalability; The simple operational ability on large, complex datasets Distribution; the ability to physically distribute data over a computer network.

In their work (Elmasri and Navathi 2011) distinguish the database approach from spreadsheet file programming by a number of characteristics; Data system self-describing nature. Insulation between DBMS and data; program-data independence. Data abstraction, Data Multiple user view support; Each user of the data has a point of entry accustomed to the required function of the user from the database. Data sharing and multi-user transaction processing.

Similarities between both view-points are apparent, emphasising the key characteristics of database as those emphasised in both works. The data modelling concept associates with Data system self-describing nature, which is in connection with the term meta-data, or data about the data stored in the DBMS. This is a crucial concept for functional reports and queries. Also, data sharing concept is stated repeatedly in both works. Multiple view support corresponds with distribution, Finally, Insulation between the DBMS and data is in act one of the forms of data persistence.

According to; Vaisman and Zimányi, (2011) Database management systems (DBMS) are software systems used for definition, creation, manipulating, and administering databases. Available literature provides multiple data modelling systems and analysis of functional dependencies for various types of database models. In general, database models can be grouped into Record-Based Data Models, Object-Based Data Models, and semi-structured data models. The Record-based data models include the Hierarchical

Model, Network data model, and the Relational Model and the entity-relationship data model. (Sumathi and Esakkirjan, 2007).

2.4 Data Models

According to; Sumathi and Esakkirajan, (2007) "*Data model is a collection of conceptual tools for describing data, relationship between data, and consistency constraints*". Data models serve to depict the logical data structure. Furthermore, a data model is a group of conceptual structures applicable to the definition of a schema.

Data Models are an integration of concepts collectively describing and manipulating data, relationships between data and constrains on data within the organization. Data models incorporate three-dimensional components; Structural, comprised of rules of constructing a database, manipulative, restricting the type of operations allowed on the data set including both structural edits to the database as well as loading and retrieving data, and Integrity constraints; ensuring the accuracy of the data. (Connolly and Begg, 2010).

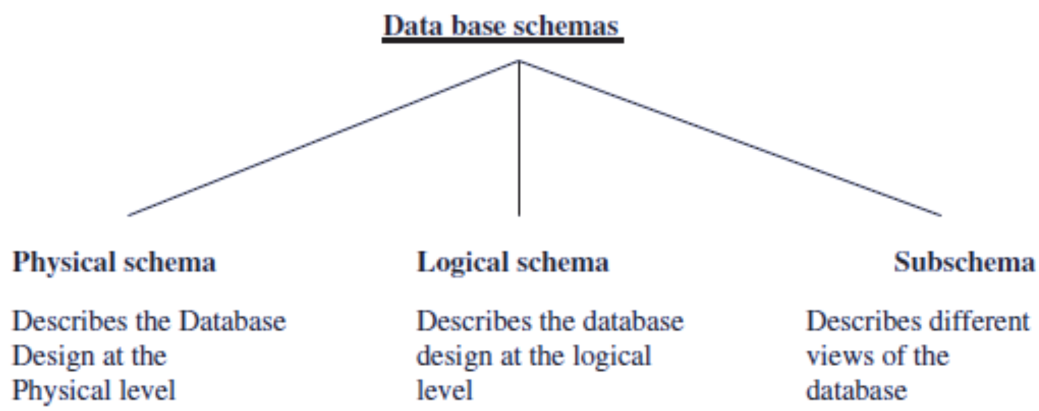


Figure 1 - Classification of database Schemas according to function
Source; Sumathi and Esakkirjan, (2007)

According to; Elmasri and Navathe, (2011) Data models can be classified into conceptual and physical. Conceptual data models are classified into object based logical model and record-based models. The object-based models include the E-R model, the Object-oriented model and the functional data model. The record-based models are; the relational model, the network model and the hierarchical model. This classification is depicted in figure 2 below.

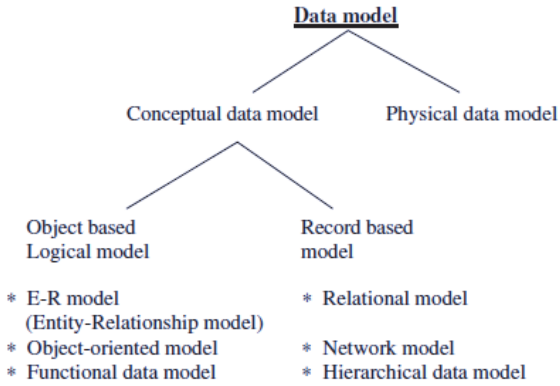


Figure 2 - Types of Data Models

Source; Sumathi and Esakkirjan, (2007)

Databases use data abstraction as a concept to suppress details about data organization and storage, only highlighting essential features, this in turn leads to improving data perception for the users. Suppression of data details does not necessarily mean the elimination of such details; however, it means that different user groups can perceive data at their preferential detail level. (Elmasri and Navathe, 2011).

The relational data model represents the collective relations among data alongside the data in tabular form. Formally, the relational model has three fundamental characteristics; structural, integral and manipulative. The structural characteristic depicts the database in form of relationship collection. From the integrity perspective, the concern is the maintenance of the data integrity in the system. This is attained through use of primary and foreign keys. The manipulative characteristic of the database model is concerned with functions such as querying the database for certain values, update of data in the database and generation of reports. (Connolly and Begg, 2010).

2.5 The Object-Oriented Database Management System (OODBMS)

Currently, the widest two DBMS are Object-Oriented database management systems and Entity-relationship database management system. The two systems are different models for data management. Object-Oriented database management systems (OODBMS) describe data at the conceptual and view levels, providing more generalized data structures. OODBMS are based on object-oriented programming, storing objects, rather than data as entities, which makes the OODBMS useful for abstract data types. The OODBMS model can be depicted using UML diagrams and incorporates association and multiplicity in deriving data relations; (Connolly and Begg, 2010). Functionally, according to; Sumathi and Esakkirajan, (2007) Object-Oriented DBMS enjoy a number of advantages, for instance; considering the dogma between functionality and stability, the object-oriented data model is more stable than functional.

However, according to; Elmasri and Navathe, (2010, p. 24) "…*their overall penetration into the database products market remains under 5% today. In addition, many object-oriented concepts were incorporated into the newer versions of relational DBMSs, leading to object-relational database management systems, known as ORDBMSs*".

This creates a significant disadvantage due to limited consensus on standards applicable to the object-oriented model. Another disadvantage of this model is that it suffers low efficiency in handling every day, simple data operations. Nevertheless, Object-oriented data models are currently used in many specialized applications like engineering, design, and manufacturing. (Elmasri and Navathe, 2011). Due to the shortcomings in the object-oriented database model, and its inadequacy to the hierarchical data types of this study, this study will then focus on the entity-relationship data model and its application to the data. The entity-relationship data model applies the concept of multidimensional data modelling which is elaborated later in this text.

2.6 Entity-Relationship Model

The entity-relationship model (E-R Model) is a top-down approach for database design, beginning with the basic entity types, relationships and entities and then building the model further down into detail by adding attributes and constraints. Entity-relationship data models are the base of schemas, which depict how the data model is constructed in the conceptual frame work of data base design. (Connolly and Begg, 2010). The E-R Model is one of the most used conceptual models for design of database applications. There is general consensus about the meanings and definitions of basic concepts in the E-R Model (Vaisman and Zimányi, 2014). An entity is a uniquely identified object that exists independently and is represented in the database. An entity type is a group of entities similar in characteristics. An attribute is a property of entity types describing entities in the database. A relationship is a meaningful association between entities including an entity from each associated entity type. A relationship type is a meaningful association between entity types. (Sumathi and Esakkirjan, 2007).

The E-R model offers a high-level, logical depiction of data in its basic abstract form of entities and that can be used in the conceptual design phase. The E-R Model is distinct by a non-technical nature, which serves in favour of requirement collection independent of end-user roles within the organization. Inter-relational relationships are not supported by the E-R model. The E-R Model depicts data in the form of entities, structured into tables representing entity types, it describes the relationships among entities and their respective attributes. The following definition of entity, entity type, relationship and attributes hold in the context of the E-R model and further in the conceptual and logical models. Data modelling as per the entity-relationship data model starts with identifying the entities, then structuring of entities into entity types, each entity type represents a set of entities in the data model. Then, relations are derived between different entities and also among entity types. (Elmasri and Navathe, 2011).

2.6.1 Entity-Relationship Types

Entities and entity types interconnect via relationships, the relationships between entities are characterized by two relationship degrees; ordinality and cardinality. In relational data models, relationships are the binding factor that ties the entities. Relationships may exist between in binary, ternary, or quaternary form. Binary relations are relations between two entities, while ternary and quaternary relations combine three and four entities at once, by the same relation. (Elmasri and Navathe, 2007)

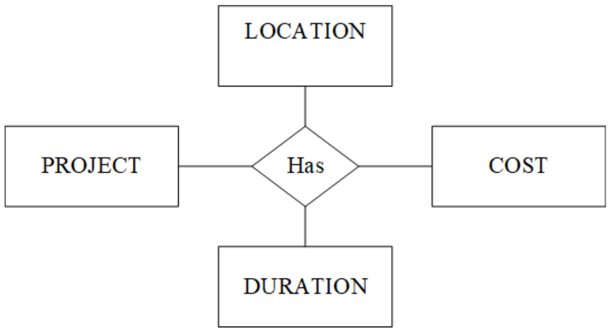


Figure 3 - Example of a quaternary relation

Source; Own contribution.

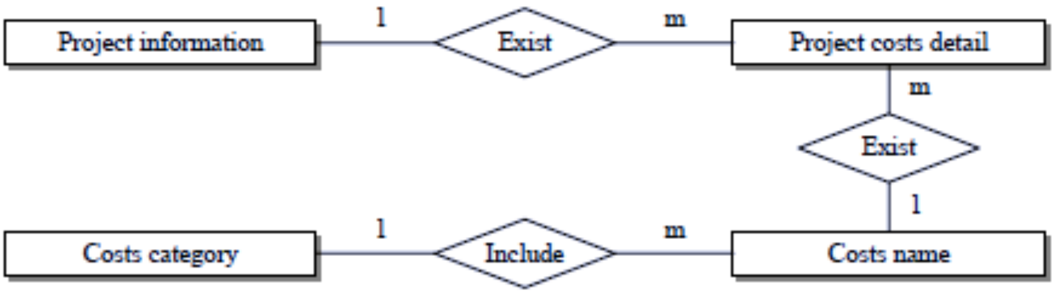


Figure 4 - Example of an Entity Relationship diagram of construction project costs

Source; Zhang and Song, (2016)

Cardinality is a degree of relationship that defines the instance of association between two entities, describing the minimum and maximum number of times and entity can participate in a relationship. (Vaisman and Zimányi, 2014)

Relationships can be broadly classified according to cardinality into three distinct relationship types; one-to-one, one-to-many, and many-to-many relationship types. One-to-many relationships associate one entity to multiple entities than one entity. One-to-one relationships are an ideal situation of the one-to-many relationships, depicting a relationship between only two entities. Many-to-Many Relationships are projects where multiple relations occur between the entities. For example, the relationship between project and cost entities is a depiction of many to many relationship types (Sumathi and Esakkirjan, 2007).

Most attributes have a single value for each entity which makes them single-valued attributes. However, some attributes may contain multiple values for the same entity, so they are called multivalued attributes (Elmasri and Navathe, 2011).

2.7 Data Normalization

Normalization targets minimization of data redundancy and anomalies caused by data update (Sumathi and Esakkirjan, 2007). It is defined as the process of analysing data to create the most efficient data structure, avoiding redundancies by breaking up large tables into smaller, more consistent ones and drawing relations between them using referential integrity (Romney and Stienbart, 2018). Normalization is built upon the theory of functional dependencies in expression of redundancies rather than repetition (Vaisman and Zimányi, 2014). The purpose of the data normalization process is to avoid abnormalities when modifying or updating the data. The process of normalization targets the minimization of attributes necessary to support the data requirements, minimization of redundancy, and creation of close logic relationships that are functionally dependent. (Connolly and Begg, 2010). The normalization process is a primary tool to validate and improve the logical design of the data warehouse, it targets the elimination of redundancy and inconsistent dependency. Redundant data is an overload on the storage capacity and is difficult to maintain and edit, as it requires editing in all the physical locations it is stored in. Inconsistent dependencies on the other hand cause difficulties in accessing data. Normalization is achieved by analysing the functional dependencies among attributes. The purposes of data normalization are avoiding redundancy, formulating data in a structure that accommodates change accurately, to avoid anomalies occurring with data update, to facilitate data constraint enforcement and to avoid unnecessary coding. (Sumathi and Esakkirjan, 2007).

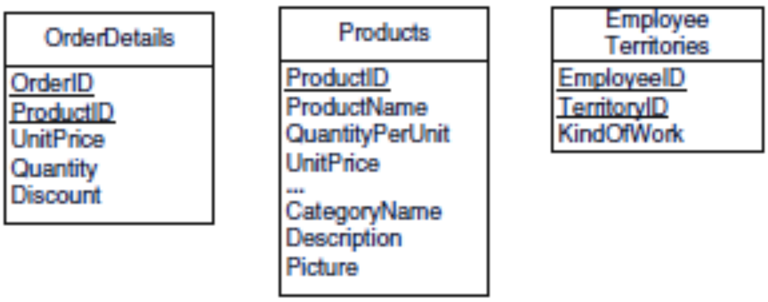


Figure 5 - Example of data and relationships that are not normalized

Source; Vaizman and Zimányi, (2014)

2.7.1 Degrees of normalization

There are multiple degrees of normalization; from first normal form (1NF) to fifth normal form (5NF), depending on the level of data normalization.

First Normal Form (1NF): The first normal form is the least form of normalization of data relations. A table is be considered to be in first normal form if all columns contain only atomic values. This implies that there is no repetition of columns for a certain record. In addition to that, all entries of the field must be of the same kind and each field (column) must have a unique name.Second Normal Form: The second normal form is normalized to a higher degree than the first. For a table to be in second normal form it must first be in the first normal form and additionally, every attribute of non-key nature must be fully dependent on the primary key. The normalization process goes on until the final fifth normal form (5NF) as illustrated in figure 6.

2.7.2 Steps of normalization

The process of normalization from unnormalized form (UDF) to fifth normal (5NF) form consists of a set of steps that are essentially applied to the table and its data in order to elevate in normal form level. First repetitions must be eliminated to reach first normal form (1NF), then practical dependencies must be removed as to reach second normal form (2NF), then transitive dependencies must be removed, leaving the table in third normal form (3NF). To increase the normalization level beyond that to the Boyce-Codd normal form (BCNF), all remaining functional dependency anomalies must be removed. Increasing in level from the Boyce-Codd normal form (BCNF), to the fourth normal form (4NF) is achieved through removing multivalued dependencies. To finally reach fifth normal form (5NF); the highest normal for, all remaining anomalies must be removed. This detailed process is depicted in figure 6.

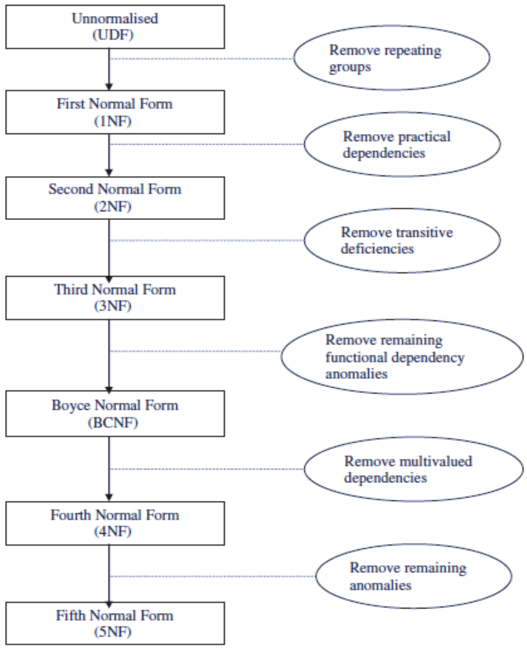


Figure 6 - Normalization Process Steps

Source; Sumathi and Esakkirjan, (2007)

On the other hand, denormalization is the process of combing tables so that they are easier to query. The process of modelling the database in the logical design in a lower normal form (1NF) or (2NF) for the benefit of faster query execution. This occurs in the event that certain attributes from different tables are commonly associated in queries. The denormalization process decreases the joint lengths in the query (Elmasri and Navathe, 2011). Denormalization is done to improve query performance (Sumathi and Esakkirjan, 2007).

2.8 Hierarchies

Hierarchies are logical structures using ordered levels to organize data in levels. They provide methods to define data aggregation. Also, a hierarchy can be used to establish a family structure. In Hierarchies, each level is logically connected to levels above and below it (Elmasri and Navathe, 2011). Hierarchies allow the representation of the data at different abstraction levels. Despite the ability of modelling complex hierarchies in conceptual design, logical models of data warehouses and OLAP systems only provide a limited set of hierarchy kinds (Vaisman and Zimányi, 2014).

2.8.1 Balanced Hierarchies

A hierarchy is balanced if at the schema level it belongs to has only one path, where all levels are mandatory. Members form a tree at the instance level, where all branches are equal in length. In conceptual multidimensional schemas, levels of

Dimension hierarchies are represented independently and are connected with parent-child relationships. Applying the mapping rules of balanced hierarchies leads to snowflake schemas, where each level is represented separately in a table, which includes keys and attributes of the level, as well as foreign keys for the parent-child relationships (Vaisman and Zimányi ,2014).

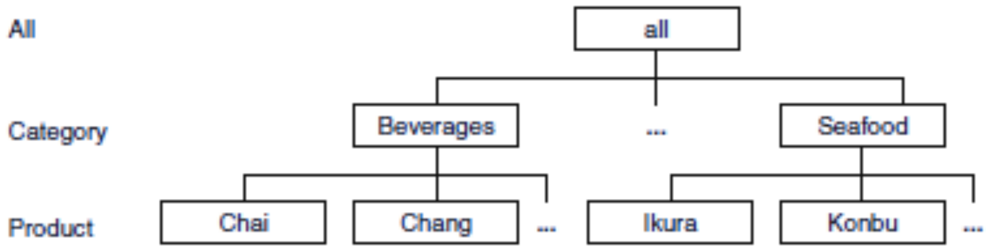


Figure 7 - Example of balanced hierarchies

Source; Vaizman and Zimányi, (2014)

2.8.2 Unbalanced Hierarchies

Unbalanced hierarchies have only one path at the schema level, but at least one level is not mandatory. In the unbalanced hierarchies, there can be parent entities without an association to child members (Vaisman and Zimányi, 2014)

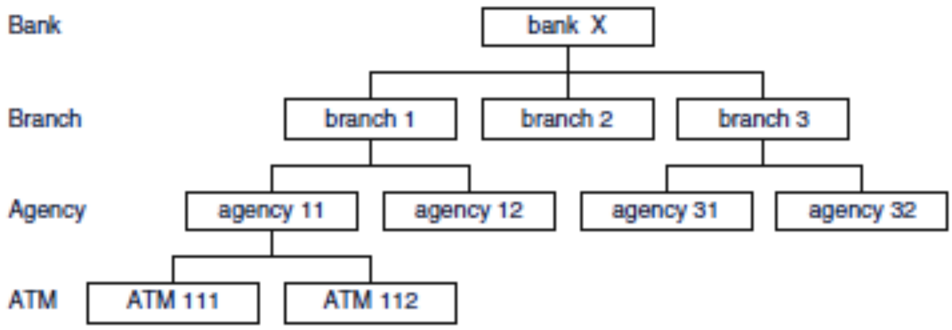


Figure 8 - Example of unbalanced hierarchies

Source; Vaizman and Zimányi, (2014)

2.8.3 Generalized Hierarchies

Generalized hierarchies occur in the situation when members of a level are of different type. This situation is depicted in the E-R model using generalization relationship. In the level of schema, the generalized hierarchy contains multiple exclusive paths sharing the same level (Vaisman and Zimányi, 2014).

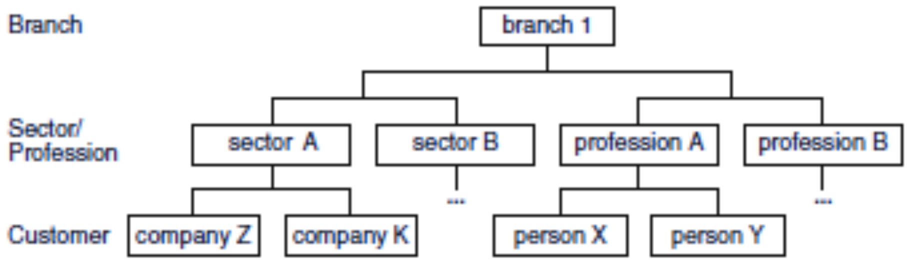


Figure 9 - Example of Generalized Hierarchies

Source; Vaizman and Zimányi, (2014)

2.9 Multidimensional Data Modelling

Multidimensional data modelling was introduced due to the limitations that the highly normalized database design introduced. This modelling allows the view of data as facts linked to multiple dimensions , facts represent the analytical focus, including attributes that are denoted as measures (Vaisman and Zimányi, 2014). In multidimensional data models, facts correspond to events associated to numeric values or measures, and are referenced using the dimension elements. Moreover, dimensions are modelled as hierarchies of elements, where each element belongs to a category, categories are organized into a hierarchy called hierarchy schema (Caniupán et al, 2012) Multidimensional data is not suitable for structuring in a relational database. A relational database is not the best data structure. The granularity of a data cube is determined by the combination of the levels corresponding to each axis of the cube (Vaisman and Zimányi, 2014).

In the multi-dimensional data model, facts are tabulated centrally representing the core of the database model containing entities with their representative attributes (measures) which enables quantitative analysis, allowing for complex queries. The facts table is linked to dimension tables, which allow the analysis of data from multiple viewpoints at once. Dimensions include hierarchical attributes, allowing users the flexibility of analysing data at various detail levels. The facts table keys are characterized by multipart keys consisting of different primary keys in the dimension tables (Vaisman and Zimányi, 2014).

Multidimensional data can also be represented by data cubes in decision support systems. The data cube represents the data factored along multiple measures of interest, denoted as dimensions. It allows the visualization and further manipulation of data by pivoting, roll-up, drill-down and slicing (Vaisman and Zimányi, 2014).

The multidimensional data model is easier for business users due to the categorization of data into well-structured dimensions. In addition to this, the data structure in the multidimensional model enables predictable processing of queries through the facts table. Another benefit is the symmetry of entry point for each dimension table into the facts table, this allows the model overall to perform in the face of simultaneously alternating query patterns from multiple user groups (Vaisman and Zimányi, 2014).

The multidimensional data model is the basis for advanced business intelligence functions such as data warehouses and On-line Analytical Processing (OLAP) systems. In some situations, there is only use of an enterprise data warehouse without data marts, or alternatively, an enterprise data warehouse does not exist. Building an enterprise data warehouse is a complex activity that is costly in both time and resources. In contrast, a data mart is typically easier to build than an enterprise warehouse. and On-line Analytical Processing (OLAP) systems are a category of analytical processing that involves tools and techniques. Data Marts support MOLAP (multidimensional OLAP), ROLAP (relational OLAP/direct query), and HOLAP (combined MOLAP/ROLAP – Hybrid OLAP) platforms for decision support (Vaisman and Zimányi, 2014).

2.10 Data Warehouses

The business requirements of organizations are evolving beyond capabilities of traditional database systems which are not well suited for these new requirements, being devised to support everyday operations not for data analysis and decision making. Consequently, data warehousing and OLAP technologies emerged as solutions for these specific requirements. Data inside the Data warehouse is characterised by being subject-oriented, integrated, non-volatile and time varying. The subject oriented nature of the data means that data warehouse targets one or more topics of analysis according to analytical requirements of management. The data inside the warehouse is the product of integrating inside operational data with data from external sources. The non-volatility of data inside the date warehouse is a reference to the specific characteristic that data removal or modification are not possibilities. The time varying nature of the data in the Data warehouse is a characteristic emphasising that the nature and evolution of data over time in a data warehouse is tracked (Vaisman and Zimányi, 2014).

A data warehouse provides a historical database orienting the storage of information towards satisfaction of decision-making requests (Sumathi and Esakkirjan, 2007). Enterprise-wide data warehouses are huge projects requiring massive investment of time and resources. Virtual data warehouses provide views of operational databases that are materialized for efficient access. Data marts generally are targeted to a subset of the organization, such as department, and are more tightly focused. (Elmasri and Navathe, 2011). A data warehouse presents an array of tools, methods, and techniques used to support knowledge workers conduct data analysis helping the decision-making processes and improving information resources (Golfarelli & Rizzi, 2009).

2.11 Schemas

2.11.1 Star Schema

On the logical level, the multidimensional model is represented by relational tables organized in specialized structures called star and snowflake schemas. These relational schemas relate a central facts table to several dimension tables. The Star schema is the simplest form of the data warehouse schema (Sumathi and Eskkirjan, 2007). A unique table is created for each dimension, even in the presence of hierarchies, which yields denormalized dimension tables.

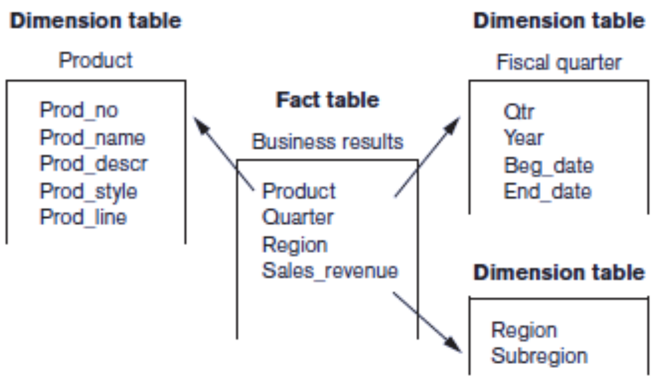


Figure 10 - Example of a star schema with facts and dimension tables

Source; Elmasri and Navathe, (2011)

2.11.2 Snowflake Schema

On the other hand, snowflake schemas use normalized tables for dimensions and their hierarchies. Then, over this relational representation of a data warehouse, an OLAP server builds a data cube, which provides a multidimensional view of the data warehouse (Vaisman and Zimányi, 2014).

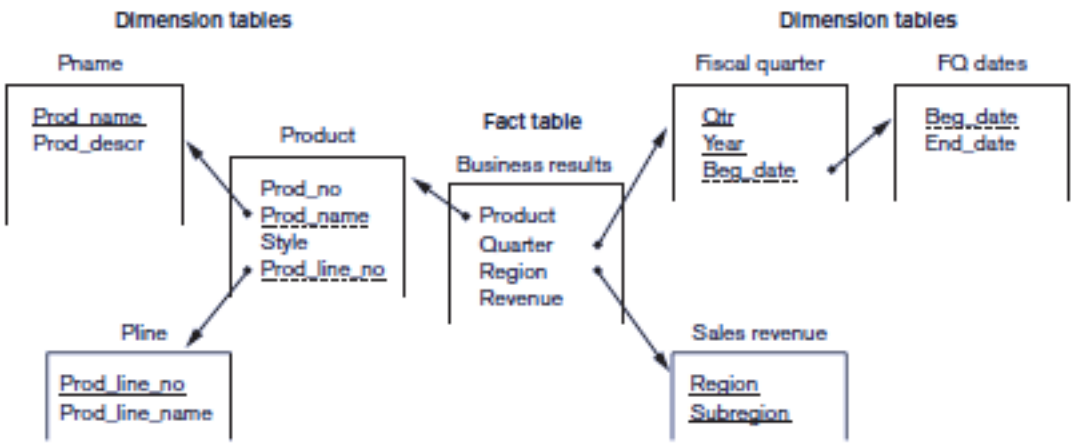


Figure 11 - Example of a snowflake schema with facts and dimension tables

Source; Elmasri and Navathe, (2011)

2.11.3 Facts Table Constellation

A constellation schema has multiple facts tables that share dimension tables. Constellation schemas may include both normalised and de-normalised dimension table (Vaisman and Zimányi, 2014).

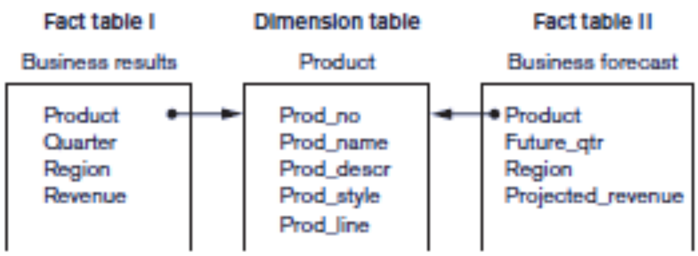


Figure 12 - Example of a facts constellation with two tables

Source; Elmasri and Navathe, (2011)

2.12 Online Analytical Processing (OLAP)

After the implementation of a Data warehouse, analytical queries must be addressed to it. Multidimensional expressions (MDX) is standard query language a multidimensional database, it can also be used in the definition of data cubes. MDX provides functionality for multidimensional databases similar to that provided by structured query language (SQL) for traditional relational databases. Online Analytical Processing (OLAP) is using queries to investigate hypothesised relationships among data (Romney & Steinbart, 2018). A wide variety of systems and tools can be used for accessing, analysing, and exploiting the data contained in data warehouses. OLAP systems allow users to interactively make queries and automatically accumulate the data contained in a data warehouse. In this way, decision makers can easily access the required information and analyse it at various levels of detail. The BI market is developing in the direction of providing sophisticated data analysis tools, exceeding the data navigation techniques utilized by OLAP systems. This new paradigm is called data analytics (Vaisman and Zimányi, 2014).

Online analytical processing (OLAP) is focused on analytical queries in particular. OLAP-oriented databases support a heavy query load. The kind of queries that involve aggregation. Processing of such queries requires, most of the time, scanning all records in a database table. In such case, indexing techniques built for online transaction processing (OLTP) are not the most efficient option in this case. Special indexing and query optimization methods are required for OLAP. Data normalization partitions the database into many tables. This would require many joints for queries involving aggregate functions, A different database model was needed to support OLAP Data warehouses, were introduced to tackle this need. Data warehouses are large repositories, consolidating internal and external data from multiple sources. Data warehouses follow the multidimensional data model. As dedicated analysis databases, data warehouses can be designed and optimized to support OLAP queries. Data warehouses are also used to support other kinds of analysis; reporting, data mining, and statistical analysis. Data warehouses and OLAP systems are based on the multidimensional model, depicting data in an n-dimensional grid, denoted data cube or hypercube. A data cube consists of dimensions and facts. Dimensions are perspectives used for data analysis data. OLAP reports from data warehouses can support the decision-making process of the top-management in large organizations (Sohrabi and Azgomi, 2019).

2.13 OLAP Operations

The multidimensional model is fundamentally characterized by allowing data viewing from several perspectives and at multiple detail levels. OLAP operations enable such perspectives and detail levels to be materialized through exploiting dimensions and their hierarchies, providing an environment for interactive data analysis (Vaisman and Zimányi, 2014).

For instance, if the user wants to compute the aggregate functions by country, they apply a roll-up operation to the country level along the dimension of the required data. Originally the cube had contained multiple values in the dimension, the new cube contains values corresponding only to country. The remaining dimensions are not affected.

Table 1 - Summary of the OLAP operations

Operation	Purpose
Add measure	Adds new measures to a cube computed from other measures or dimensions.
Aggregation operations	Aggregate the cells of a cube, possibly after performing a grouping of cells.
Dice	Keeps the cells of a cube that satisfy a Boolean condition over dimension levels, attributes, and measures.
Difference	Removes the cells of a cube that are in another cube. Both cubes must have the same schema.
Drill-across	Merges two cubes that have the same schema and instances using a join condition.
Drill-down	Disaggregates measures along a hierarchy to obtain data at a finer granularity. It is the opposite of the roll-up operation.
Drill-through	Shows data in the operational systems from which the cube was derived.
Drop measure	Removes measures from a cube.
Pivot	Rotates the axes of a cube to provide an alternative presentation of its data.
Recursive roll-up	Performs an iteration of roll-ups over a recursive hierarchy until the top level is reached.
Rename	Renames one or several schema elements of a cube.
Roll-up	Aggregates measures along a hierarchy to obtain data at a coarser granularity. It is the opposite of the drill-down operation.
Roll-up*	Shorthand notation for a sequence of roll-up operations.
Slice	Removes a dimension from a cube by fixing a single value in a level of the dimension.
Sort	Orders the members of a dimension according to an expression.
Union	Combines the cells of two cubes that have the same schema but disjoint members.

Source; Vaizman and Zimányi, (2014)

2.14 The design process of the Data warehouse system

There is no consensus on the stages for data warehouse design. The two main approaches used for database design are top-down and bottom up approaches. The top-down approach is the situation where the whole system operation is known and defined. After that the system is decomposed into lower level units and each unit is understood individually (Kaul *et al*, 2017).

Modelling in the top down approach starts at high level, applying top-down refinements to identify lower level entities and relationships among them. The top down approach utilises E-R diagrams for illustration of the data model Most available literature in the data warehouse domain uses a bottom-up approach to design based on the relational model, using the star, snowflake or constellation schemas (Connolly and Begg, 2010).

The bottom-up approach identifies individual components as it is not known how the whole system works. The focus of the bottom-up approach is the design of the components (Kaul *et al*, 2017).

According to; Vaisman and Zimányi, (2014) Data warehouse design follows the assumption that Data warehouses are special databases dedicated to analytical purposes. The Data warehouse design follows the traditional design phases; Requirements selection, Conceptual Design, Logical Design and Physical Design.

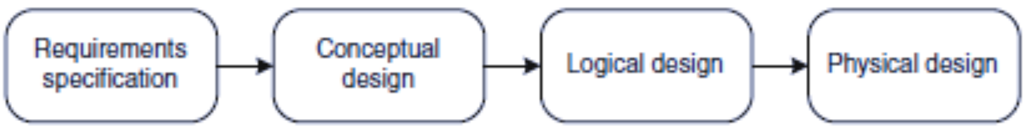


Figure 13 - Traditional Phases of Data warehouse Design
Source; Vaizman and Zimányi, (2014)

The four major phases are undergone sequentially and separately to guarantee data independence, ensuring that lower level schemas do not affect higher-level schemas

2.14.1 Requirement Collection and Analysis

The requirement collection is the process of collecting and analysing information about the organizational part to be supported by the database. The information collected from different user groups is specific for each user view, this information includes; a detailed description of data, details about how data is used, any additional requirements from the new database system.

The information is further analysed, for identification of the features or requirements to be included in the database system. The requirements are documented in requirements specification documents for the system requirements are identified. The requirement specification stage is preliminary to the database design. It is critical to identify the required functionality of the system.

At this stage, it is also necessary to identify and decide how to approach user views for multiple user groups, with different user views. There are three approaches to the management of user views in the requirements collection phase; a centralized approach, a view Integration approach or simply combining both approaches.

In the centralised approach requirements for each user view are grouped into a single set of requirements for the new database system. The data model designed in the consequent design stages is a global model, representing all user views. The process is depicted in figure 14.

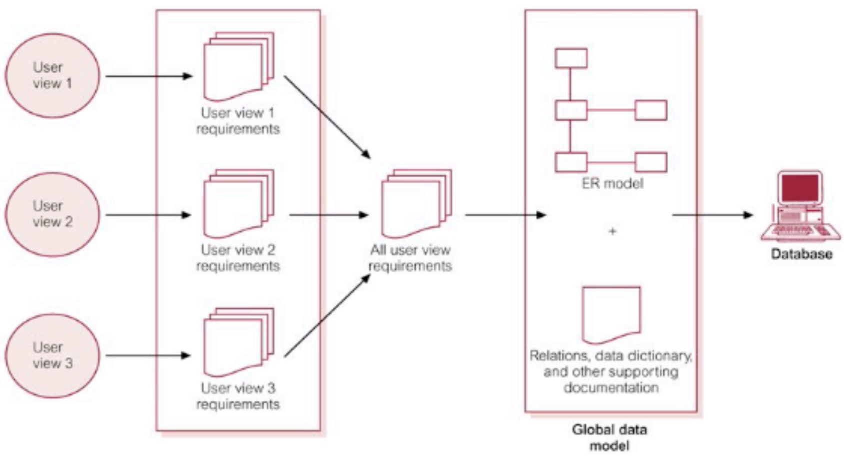


Figure 14 - The centralized approach to managing multiple user views
Source; Connolly and Begg, (2010)

In the view integration approach, requirements for distinct user views are listed separately. Local data models are developed individually for each user group then later merged in the database design stage into a global data model. For complex systems, combining both the centralised and the view integration approaches is applicable for management of multiple user views (Connolly and Begg, 2010).

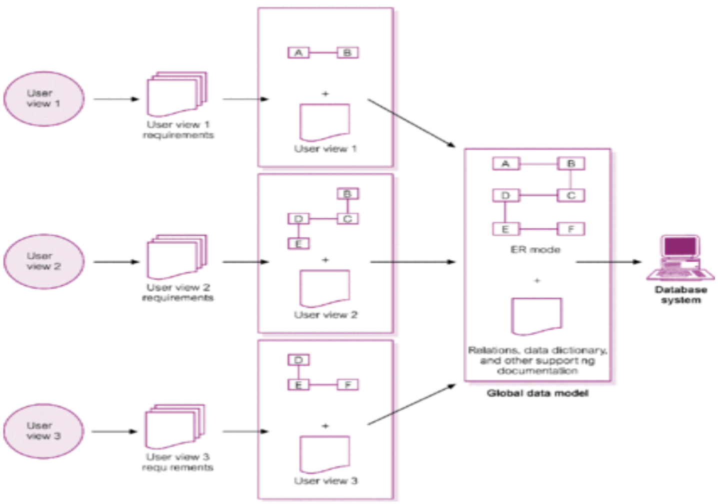


Figure 15- The view integration approach to managing multiple user views
Source; Connolly and Begg, (2010)

2.14.2 Conceptual Design

Conceptual modelling is the process of structuring a model of the data independently of execution details such as the selection of the database management system (DBMS) and physical erudition. The primary objective of the conceptual design is to depict the data in a user-oriented form. This is achieved through a theoretical model identifying relevant concepts of the data application. Both object-oriented and record-based data models are commonly used in conceptual modelling. In the case of object-oriented modelling, the notation of Unified Modelling Language (UML) is used.

There are two approaches in conceptual database design modelling, either according to Top-down or bottom-up approach. In the top-down approach, a unique schema is built up from user requirements, globally without differentiation in the schema itself, later a view division for each user group is performed. On the other hand, in the bottom-up design schemas are separated for each user groups according to their requirements and schemas are later integrated into a global conceptual schema

2.14.3 Logical Design

Throughout the logical design stage of the database development, conceptual representation is transformed into a logical model. Mapping rules are utilized to ensure the representation of the model in an adequate manner. The most commonly used model for logical design is the entity-relationship model, which is a highly normalized model, the high level of normalization supports structured queries.

2.14.4 Physical Design

The physical design embodies the logical representation into a physical design on a particular Database Management System DBMS platform. This is the last step in the design process of the database system. During the physical design phase gathered data throughout the logical design phase is converted into descriptive of the physical database structure. Physical design decisions are mainly driven by query performance and database maintenance aspects.

3. Data Warehouse Concept in Construction Costs

This chapter elaborates the basic principles in construction costs management and provides an overview of the construction costs classification systems, emphasising the hierarchical relationships of construction items. It is structured as follows;

- Data Warehouse Concept in Construction Costs
- Critical Success Factors for BI Applications
- The Cost Data Structure in The Construction Industry
- Company Overview.

The basic concept of a data warehouse as a data structure was introduced by IBM in the 1990s. Data warehouses address several problems that came with business processes and information management. This was to understand the data flow from operational systems to decision support environments. Accordingly, the operational systems were established to support day-to-day business operations through maintaining and updating databases for order entry, billing and transactions. The concept highlighted the limitations of operational systems for decision support and especially showed the importance of more analytical information systems.

Following that, approximately in the mid-2000s, an emergence for the application of data warehouses in the construction industry took part. The development of the Construction Management Decision Support System (CMDSS) prototype was established to investigate the application of the warehouse in construction management. CMDSS was developed to predict future inventory patterns and trends with less time taken. While only used in a construction project of a student dormitory at Hong Kong Polytechnic University, CMDSS showed great promise because it permitted a multi-view-based interaction between systems and users alike. Another prototype decision support system was developed to determine the most appropriate sites for residential houses. The system incorporated the GIS software and the AHP tool. Another work developed a Project-oriented Data Warehouse (PDW) for contractors through the use of client–server architecture. The construction was categorized into four different groups, including performance, materials, estimates and contracts with 16-dimension tables and ten fact tables. The PDW showed that it has captured the nature of the construction business properly and it served as a management tool with high efficiency for the construction data gather through the life cycle of the facility.

According to the summary of the dashboard reports of the module, the project costs were dropped down, the time and cost were also estimated and the S-Curve of the schedule and actual progress (Sugata et al, 2016).

3.1 Critical Success Factors for BI Applications

According to; Yeoh and Popovic (2016); one of the main problems facing the BI application in the business domain is the poor understanding of the Critical Success Factors (CSFs) whilst implementing BI system initiatives. A standard implementation of a BI system contains multifaceted Intelligence System (IS). Infrastructural projects such as Enterprise Resource Planning (ERP) systems implementation. However, despite that, little contextual understanding is thus given to guide a project team tasked with the implementation of a BI system. In their work, they present Critical Success Factors that would lead to success of implementation of the BI model. There are three sections that require attention: The Organization, the Process and the Technology. The organization would require dedicated management support and sponsorship along with a clear vision and an established business case. For the process, a business centred championship and balanced team composition should be vital, along with a business-driven approach for development and user-oriented change management. As for the technology, a flexible, scalable and business focused technical framework is mandatory along with sustainable data quality and integrity. The success criteria are measured through the system and information quality and system use of the infrastructural performance and the budget and time schedule of the process performance.

Sugata et al. (2016) developed a case study that focused on the application of business intelligence. Their work aimed to provide further information on Key Performance Indicator (KPI) and how they can aid the executives of a company to make fast and precise decisions in order to vastly improve the performance of the project, especially in the cost control. According to the summary of the dashboard reports of the module, the project costs were dropped down, the time and cost were also estimated and the S-Curve of the schedule and actual progress. The results of the work showed that the BI application model can access data warehouse online providing information analyses fast and accurately with high efficiency. The visual display also proved to ease the reading of the results of the data analysis. BI applications provided a speedy report preparation evaluation of 99.5% in comparison to manual reporting processes. The results of the work showed that the BI application model can access data warehouse online providing information analyses fast and accurately with high efficiency. The visual display also proved to ease the reading of the results of the data analysis. BI applications provided a speedy report preparation evaluation of 99.5% in comparison to manual reporting processes.

3.2 The Cost Data Structure in The Construction company

The cost-related data in the company currently is managed using spreadsheets with a format commonly known as the bill of quantities (BOQ) being the most dominantly used. The bill of quantities is an important functional document in the management of construction projects. The BOQ assumes a tabular form, with multiple entries of work items being listed against a specific code. Quantities for each item are measured from the drawings and listed against the relevant item. A construction work item is a group of construction activities defined and measured by a tangible end result; however, work items involve intangible activities that often vary in nature. ()

Items of the bill of quantities (BOQ) items are structured in various methods according to construction standard procedures and regulatory bodies in each country. The most common structures for work items are the UNIFORMAT II, the MasterFormat 95, the elemental standard form of cost analysis, the German Institute for standardization building costs (DIN 276) and the Czech Class of building structures and works (Třídník stavebních konstrukcí a prací). (Afsari and Estman, 2016)

For the purpose of the design and development of this database, the costs are structured according to the elemental method as per Building Cost Information Service (BCIS) Elemental Standard Form of Cost Analysis. The elemental standard form of contract was introduced in 2012 to adapt to the new rules of measurement (NRM) issued by the Royal Institute of Chartered Surveyors. The elemental form of classification is the standard used in the company; however, some projects may adopt other classification methods according to the client requirements.

Elemental Construction Cost Analysis: A structural hierarchy of construction elements for purposes of cost estimation and management.

Bill of Quantities (BOQ) Document containing all construction work items necessary for project completion, their quantities, units of measurement, unit rates and total cost.

Order of Magnitude: An overview of estimated project costs at early design phases where little to no details are available.

Table 2 – Detailed (elemental) Bill of Quantities

	ELEMENT	Element				
		Total Cost £	Cost per m^2 GIFA	Unit Quantity		Unit Rate
1	SUBSTRUCTURE				m^2	
2	SUPERSTRUCTURE					
2.1	Frame				m^2	
2.2	Upper Floors				m^2	
2.3	Roof				m^2	
2.4	Stairs and Ramps				Nr	
2.5	External Walls				m^2	
2.6	Windows and External Doors				m^2	
2.7	Internal Walls and Partitions				m^2	
2.8	Internal Doors				Nr	
	Total Superstructure					
3	INTERNAL FINISHES					
3.1	Wall Finishes				m^2	
3.2	Floor Finishes				m^2	
3.3	Ceiling Finishes				m^2	
	Total Internal Finishes					
4	FITTINGS, FURNISHINGS AND EQUIPMENT				m^2	
5	SERVICES					
5.1	Sanitary Installations				Nr	
5.2	Services Equipment				Nr	
5.3	Disposal Installations				Nr	
5.4	Water Installations				m^2	
5.5	Heat Source				kW	
5.6	Space Heating and Air Conditioning				m^2	
5.7	Ventilation Systems				m^2	
5.8	Electrical Installations				m^2	
5.9	Fuel Installations				m^2	
5.10	Lift and Conveyor Installations				Nr	
5.11	Fire and Lightning Protection				m^2	
5.12	Communication, Security and Control Installations				m^2	
5.13	Specialist Installations				m^2	
5.14	Builder's Work in Connection with Services				m^2	
	Total Services					
6	PREFABRICATED BUILDING AND BUILDING UNITS				m^2	
7	WORK TO EXISTING BUILDING					
7.1	Minor Demolition and Alteration Works				m^2	
	Total Work to Existing Building					

Source; Elemental Standard Form of Cost Analysis Principles Instructions Elements and Definitions - 2012 - BCIS

In the elemental classification format, the construction items are analysed by building, each building is separated and has a separate BOQ. Items are grouped according to elements of the building, for example; the sub-structure, super structure, finishes, services and external works. (*Elemental Standard Form of Cost Analysis Principles Instructions Elements and Definitions, 2012*)

security procedures as well as the management ability to utilize the data extracted for market trend analysis through pivot functions in spreadsheets. It was agreed that a series of meetings would follow to discuss individual user group requirements. It was also agreed that a questionnaire would be presented to the users to determine their specific requirements through questions about the current workflow, the users' respective roles and their perceptions on how to improve the process overall by improving their roles.

The second meeting held was with the senior cost engineers who are currently the pivot group in the process of cost estimates preparations. During the meeting the senior cost managers presented their questions regarding the possibility of executing specific functions through the DBMS. Particularly of interest to this user group were the segregation of costs per level of item hierarchy, costs per area of the gross floor area and per functional units. During the meeting, the engineers presented the concepts of elemental classification, and introduced the basic principles of construction cost benchmarking. Also, they elaborated that construction item structure used within the company is of hierarchical nature and that the costs per functional unit and gross floor area are standard benchmarking methods in the cost management process of the construction industry. Also, during this meeting, the user requirement questionnaire was presented to document individual users' requirements.

The third meeting was conducted with the junior cost engineers. The current role of this user group is simply to measure the quantities off the drawings and list down the specifications highlighting high-cost items for the senior engineers to price according to their experience. The idea of a database system to store cost data was introduced and responses were collected. The questionnaire was presented to this user group as well for their requirement collection. The meetings were documented by agendas and minutes for further reference in the design stages of the database solution.

4. Data warehouse Model Implementation

This chapter elaborates the practical methods used in the design of the database. It is structured as follows;

- Company Overview
- Pilot Data
- Requirements Collection

4.1 Company Overview

The company is a construction management consultancy, operating in the Czech market since 1992. The main services provided by the company are project management, cost management and quality management of construction projects. The project management department focuses on construction project management and quality management department focuses on the total quality management (TQM) of construction activities. The cost management department is an independent department rendering services related to construction cost management, in different stages of the project, for example; the estimation of costs for budgeting, management of tendering process and certification of interim progress payments during the construction phase.

4.2 Pilot Data

The Data from pilot projects was obtained in spreadsheets form, tabulated according to the elemental classification of construction items, with the total amount for each work item denoted against the work item and the specific work item code.

Pilot projects were selected on basis of historical cost significance and to represent diverse sectors available in the company portfolio.

4.3 Requirements Collection

The collection of requirements from the different user groups occurred over a series of meetings and questionnaires. The meetings were held to gain insights into each user group tasks and current limitations from the spreadsheet technology adopted. The users were grouped into three user groups, namely; the company management, the senior costs engineers and the junior cost engineers.

The first meeting was held with the company management represented by the company Director and the head of cost management department. The proposed meeting agenda was to discuss the current problems within the cost management department, particularly the deficiencies in the cost estimate preparation process and identify the weak points that require tackling. The alignment of the database with the company strategic vision and directives was also discussed, especially in terms of the DBMS conformance to the

4.3.1 Design of Requirement Collection Questionnaire

The questionnaire was designed to tackle the current process of the cost estimates preparation in the company and its deficiencies. The questionnaire focused on one particular department within the company; the cost management department. The questionnaire targets inquiring about the process weaknesses and proposed solutions from each individual user's perspective. The questionnaire was designed in form of direct, short answered questions, oriented towards gaining a clear understanding of the current process problem and design a solution that solves the problem and mitigates the risks of its reoccurrence.

The questionnaire questions were grouped into categories, the first category of questions addressed the user perceptions of the current process and whether they believe a data warehouse solution would be of benefit to the process. The second category of questions focuses on user experience and perception of their roles in the process. Thirdly, the final category targets the suggestions of individual users for the database functions and further development.

4.3.2 Analysis of Responses to The Requirement Collection Questionnaire

The user groups responses were collected and analysed, each from their view points. The responses were tabulated and summarized. The following tables show the questions and responses of main user groups.

The first user group; management have indicated that analysis, trending and bench marking of data analysis from the system is their main objective, in line with the strategy of the company. They have mostly specified their need for improvement of the current practices in the company, each noting what they perceive as the most important target area for improvement

Table 3 – User group 1 (Management) responses to the requirements questionnaire

USER GROUP	MANAGEMENT				
USER	A	B	C	D	E
Question	*On a scale from 1 to 5, 5 being the highest. how important is analysis of historical data trends for you as an executive?*				
Response	5	4	4	3	5
Question	*Does your job require advanced data analytics?*				
Response	Yes	Yes	Yes	Yes	Yes
Question	*Are you comfortable with the quality of the current practice of data analysis?*				
Response	No	No	No	Yes	No
Question	*If your answer to the above question was no, what would you like to improve?*				
Response	Reliability	Verification of data	Timeliness	Nothing	Data analysis
Question	*What is the top priority for the Data warehouse system from your perspective*				
Response	Security	Robustness	Ticketing System	Ability to see user actions	cross-functionality

Source; Management responses to the requirements questionnaire.

The second user group; the senior engineers, affirmed the need for a change in the process design for issuance of cost reports. They specified the importance of security in the Data warehouse system implemented and they mostly agreed on the importance of integrating a Data warehouse solution for the improvement of the process.

Table 4 – User group 2 (Senior Engineers) responses to the requirements questionnaire

USER GROUP	SENIOR COST ENGINEERS				
USER	Senior Cost Engineer - A	Senior Cost Engineer - B	Senior Cost Engineer - C	Senior Cost Engineer - D	Senior Cost Engineer - E
Question	*How would you describe the current process in your department?*				
Response	Inefficient	Slow	Needs improvement	Not bad	Unreliable
Question	If your answer to the above question was negative. What do you is lacking in the process?				
Response	Procedure	responsibility sharing	an advancement	N/A	Yes
Question	On a scale from 1 to 5, 5 being the maximum limit, how much would you rate a Data warehouse solution for your process?				
Response	4	3	3	2	5
Question	What are the most important things in a database system from your view point?				
Response	Security	No	Security	User Experience	Yes
Question	Do you think the is room to improve the current paradigm?				
Response	Yes	Yes	No	yes	no

Source; Seniors' responses to the requirements questionnaire.

The third user group; the junior engineers expressed their dissatisfaction with the current limitations on their roles and confirmed their need for a functional solution to assist them assume more responsibilities for issuance of cost reports. They specified the importance of security in the Data warehouse system implemented and they mostly agreed on the importance of integrating a Data warehouse solution for the improvement of the process.

Table 5 –User group 3 (Junior engineers) responses to the requirements questionnaire

USER GROUP	**JUNIOR COST ENGINEERS**				
USER	**Junior Cost Engineer - A**	**Junior Cost Engineer - B**	**Junior Cost Engineer - C**	**Senior Cost Engineer - D**	**Junior Cost Engineer - E**
Question	*Are you satisfied with you current job task*				
Response	No	No	Yes	Yes	No
Question	*If your answer was no to the above question, please elaborate*				
Response	More responsibilities	Interesting work	Yes	No	motivation
Question	*How would you rate the current process on a scale from 1 to 5, 5 being the most?*				
Response	Yes	Yes	Yes	Yes	Yes
Question	*On a scale from 1 to 5, how important is the ability to access all functions within the Data warehouse for you?*				
Response	Yes	Yes	Yes	Yes	Yes
Question	*On a scale from 1 to 5, how important is the Data warehouse flexibility for you?*				
Response	5	4	5	3	4

Source; Juniors' responses to the requirements questionnaire.

4.4 Overview of The Cost Report Preparation Process

The process of preparing cost reports is a function of the cost management department in the company. Cost reports are prepared regardless of the company service scope on the project, whether cost, project or quality management. The cost report is an estimate of the project costs based on the scope of construction-related activities required for the project completion. The report is based on the integration of the project bill of quantities (BOQ) and order of magnitude. The BOQ is usually calculated on a spreadsheet, with items listed against the measured quantities and units of measurement, estimated unit rates and total amount for each item. The order of magnitude is the project document specifying the cost magnitude according to the design and specifications, it is created by benchmarking the current projects to similar previous projects.

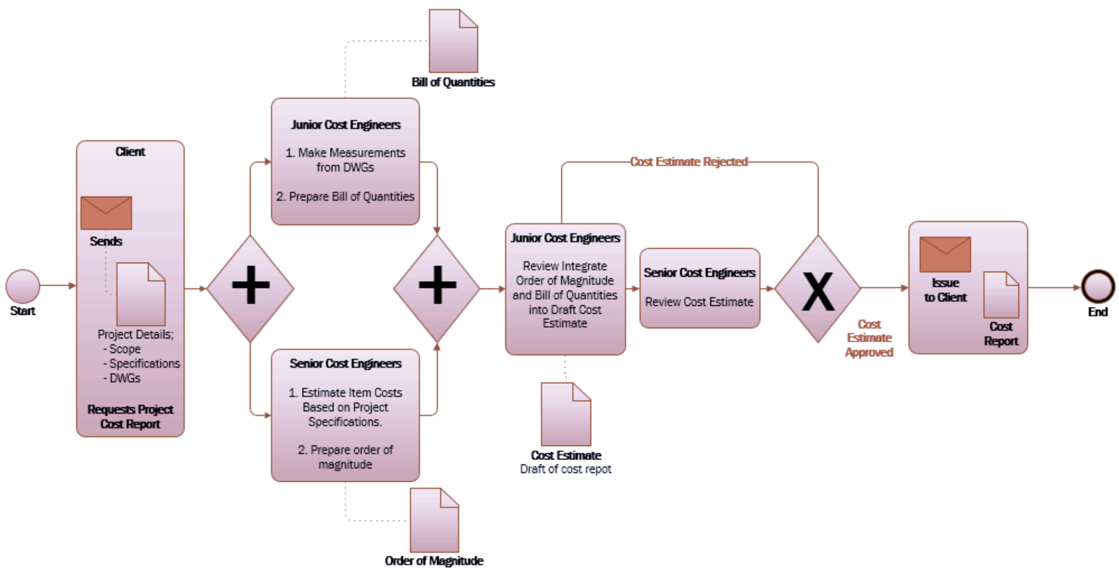


Figure 16 - Current Process for the Preparation of Cost Report

Source; Own elaboration.

Currently, when receiving a cost estimating request from a client, along with all necessary project details like the project scope, specification and drawings (DWGs) the common practice in the company is that the junior and senior cost engineers work with the available documents in parallel and simultaneously. Junior cost engineers make measurements from drawings, in a process called quantity take-off, accordingly they prepare the bill of quantities with items, quantities and units. The seniors in the meantime estimate the costs of items and prepare the outline of the order of magnitude. After finalization of both the BOQ and the order of magnitude, junior cost engineers integrate both documents into a draft version of the cost report called the cost estimate. The cost estimate is reviewed by seniors and if approved, the cost report is issued to the client based on this draft estimate.

The current process is long and demanding for the senior cost managers, especially that they have to estimate the costs and prepare the order of magnitude, then again review the cost estimate. This inefficiency occurs due to the limited experience of juniors in regard to construction costs estimation and benchmarking.

The skill of costs estimation and benchmarking comes as any skill with practice and experience; however, it is partially affected by having a range of data from different projects, which is the know-how. The objective function of the data warehouse is to provide this know-how to users who are lacking it. The proposed solution would then, when fully utilized, reduce the work required by seniors on the preparation of cost reports, allowing them to review more estimates, reducing the back-log of cost reports currently pending review, modification and issuance.

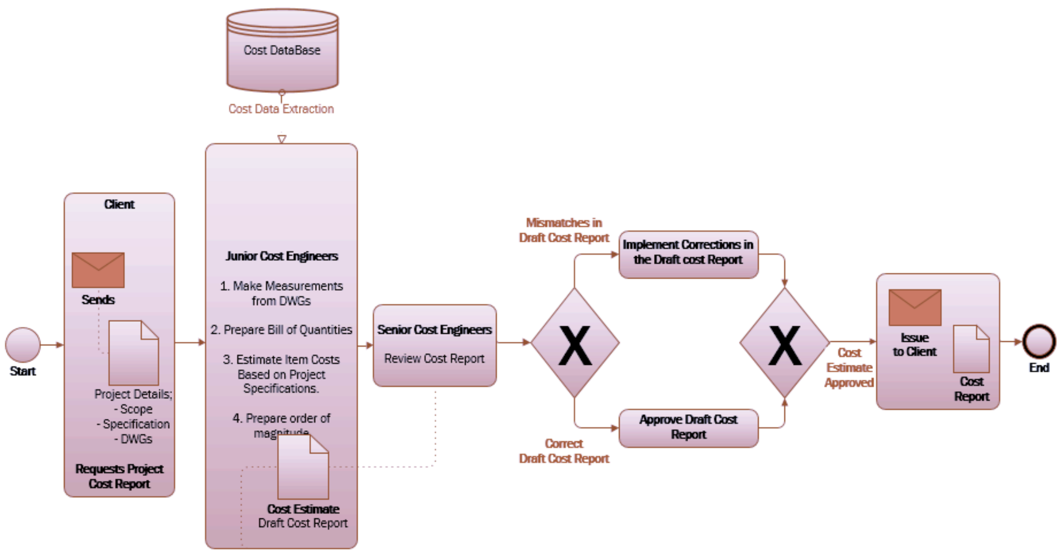


Figure 17 - Future Process for Preparation of cost Report after full utilization of the data warehouse.

Source; Own elaboration.

The process after incorporation of the data warehouse would allow juniors to estimate item costs and prepare the order of magnitude document using some OLAP and pivot analysis of data extracted from the data warehouse, this would eliminate the need for additional work of seniors on this process and would limit their role in this to the review of cost reports. In addition to decreasing the backlog of cost reports pending review this would also increase the efficiency of the process by allowing juniors to perform advanced tasks, which adds value to the company overall. It would also increase the availability of senior cost engineers for client activities.

4.5 Entities and Relationships Among Them

The data provided by the company was a cost summary for five projects, denoted pilot projects for the purpose of the data warehouse creation. The costs were listed according to work items, work items were hierarchically grouped into activities and work types, according to the elemental classification. The sum of costs for each group of items (the activity) represents the activity cost. Activities grouped together form a work type, which has cost equal to the sum of activity costs making up the work type. The project main datasheets were also provided by the company, containing information about the project; for example, location, the project type, the project value in Czech Korunas, the gross floor area of the project (GFA), and the number of units per project.

The main entity types of the data model in its abstract form are the projects, the work items, and time. Each project has multiple work items and has a time frame.

4.6 Design of the data base

4.6.1 Conceptual Design and schema

In the conceptual phase of the design the main entities and attributes were defined and primary relationships among them were drawn. The main attributes for each entity were also defined and listed. The data warehouse model applied was the multi-dimensional relational model. The ability of this model to incorporate hierarchies and execute multiple queries were the main reasons for the selection of the model.

The model consists of a facts table surrounded by dimension tables that represent the entity types. Each entity type has entities and attributes, the star schema was depicted using the entity-relationship model. The Dimensions are depicted in the E-R conceptual model, showing a central facts table model, interconnected with each dimension; project, time and work items.

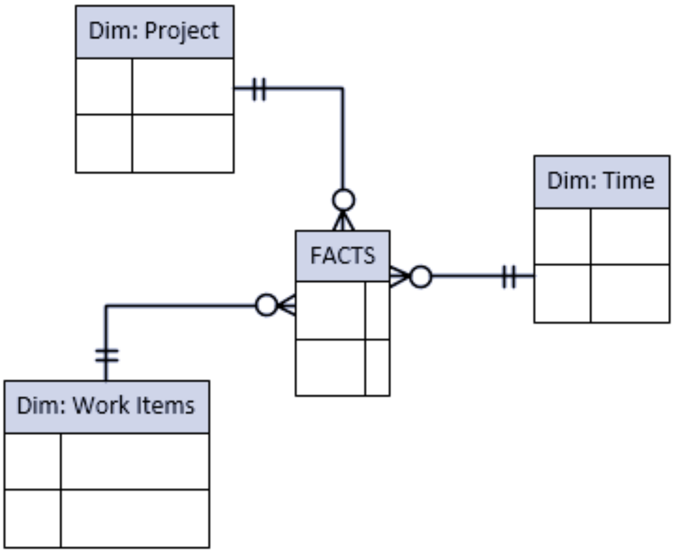


Figure 18 - Cost Data warehouse Conceptual Star Schema
Source; Own elaboration.

Extending the conceptual model further, it is necessary to determine the key entities and attributes belonging to each entity type. Multiple attempts were made to design the snowflake schema of the conceptual model and apply it to the logical model. The limitations of hierarchies; however, offered little room for manoeuvring with the data structure.

4.6.2 Logical Design

The hierarchies and relations between work items, work activities and work types were modelled in multiple attempts to provide minimal joints in queries. Other important criteria followed in the design were the referential integrity which dictates avoiding duplicate values for primary keys, and the normalization of the data tables. The final model adopted was to cluster the work items, activities, and types in the work items dimension as separate entities and create an auto-number primary key that avoids repetition when connecting to the facts table.

Table 6 – Construction Work Types

Code	Description
0	FACILITATING WORKS
1	SUBSTRUCTURE
2	SUPERSTRUCTURE
3	FINISHES
4	FITTINGS
5	SERVICES
6	PREFABRICATED BUILDING
7	WORK TO EXISTING BUILDING
8	EXTERNAL WORKS
9	MAIN CONTRACTOR'S PRELIMINARIES

Source; Own Elaboration, data as provided by company.

When designing the logical model, it was important to also determine in which table to load the cost data, whether it was to be centred in the facts table or added to the dimension table. Further analysis of entities, attributes and relations in both the project and work items tables was made.

The project attributes; sector, location, company service, project type, project area, and number of units were all categorial in nature and had forms of a one-to-one relationships to the project, having no further many-to-many associations nor being on a different level of hierarchy. Unlike the costs, which were hierarchical, so the costs were excluded from the dimension table project.

Table 7 – Construction Work Types split into activities

Code	Description
0	**FACILITATING WORKS**
0_1	TOXIC/HAZARDOUS/CONTAMINATED MATERIAL TREATMENT
0_2	MAJOR DEMOLITION WORK
0_3	TEMPORARY SUPPORTS TO ADJACENT STRUCTURES
0_4	SPECIALIST GROUNDWORKS
0_5	TEMPORARY DIVERSION WORKS
0_6	EXTRAORDINARY SITE INVESTIGATION WORKS
1	**SUBSTRUCTURE**
1_1	SUBSTRUCTURE
2	**SUPERSTRUCTURE**
2_1	FRAME
2_2	UPPER FLOORS
2_3	ROOF
2_4	STAIRS AND RAMPS
2_5	EXTERNAL WALLS & EXTERIOR FINISH
2_6	WINDOWS AND EXTERNAL DOORS
2_7	INTERNAL WALLS AND PARTITIONS
2_8	INTERNAL DOORS
3	**INTERNAL FINISHES**
3_1	WALL FINISHES
3_2	FLOOR FINISHES
3_3	CEILING FINISHES
4	**FITTINGS, FURNISHINGS AND EQUIPMENT**
4_1	FITTINGS, FURNISHINGS AND EQUIPMENT

Source; Own Elaboration, data as provided by company.

The time dimension was similar to the project dimension as the project time-related data had a one-to-many relationship with projects, which influenced the logical design for this dimension in the snow flake schema to be in the form of only one table representing the time dimension, without further hierarchical clusters.

The dimension of the work items, however, was hierarchical in nature, as each work type has many work activities and each work activity has many work items. The granularity level of the data stops at work items which are the basic units of the elemental classification of construction items. The following table elaborates the hierarchical nature of work items and their relation to work activities and eventually to work types.

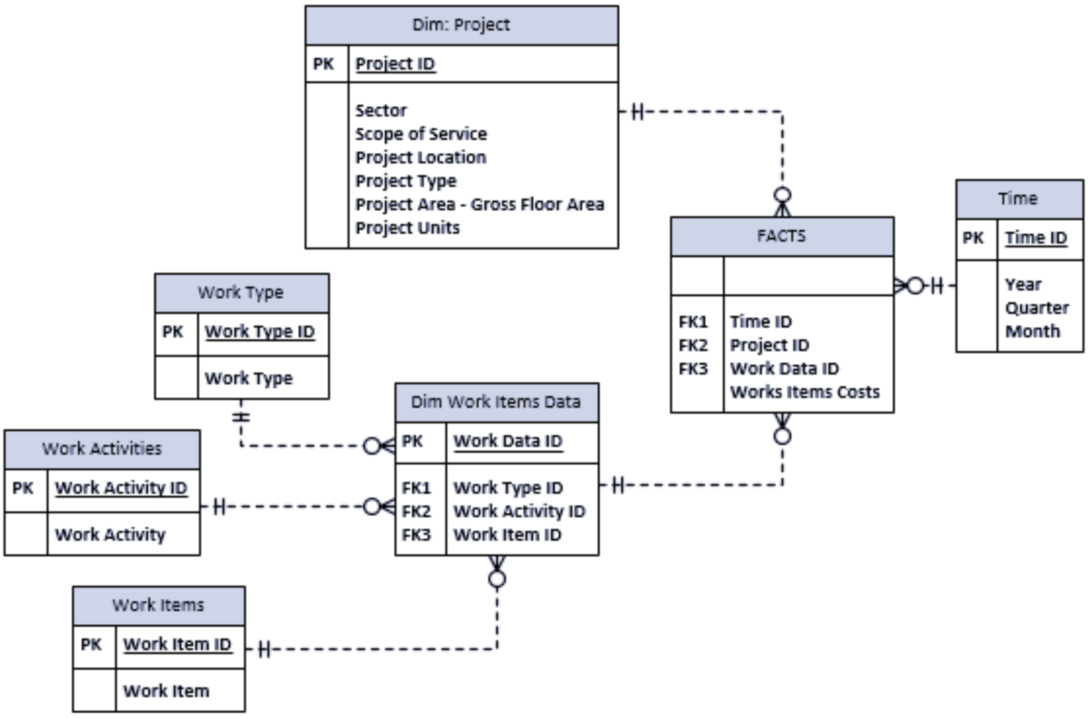


Figure 19 - Logical Data warehouse Snowflake Schema

Source; Own elaboration.

The modelling of the work items dimension assumed a snowflake schema with the dimension table including attributes from the work type, activity and items tables as foreign keys and automating a unique primary key denoted Work Data ID for connection with the facts table. In the facts table the project ID and the Work Data ID were added as well as time ID. The costs of work items were loaded into the central facts table as the costs share many-to-many relationship with each project from one side and also with work items, activities and types from the other. Adding them to either dimension would have increased the joints and lengths of queries and complicated the model.

4.6.3 Selection of the DBMS platform

The criteria for selecting the Database management system (DBMS) platform as outlined through meetings with stakeholders and as defined in the requirement selection were a user friendly, especially for new users, open source software that satisfies the minimum-security criteria while enabling user views and ticketing. A research for the best alternative of the DBMS management system was carried out and different alternatives were short listed. The most convenient solution found Microsoft Access, being a conventional data warehouse tool and sharing many characteristics with the spreadsheet client currently utilized by different users groups.

4.7 Physical Model of the data warehouse

Construction of the Physical Model on the DBMS

The physical model was constructed according to the logical design selected and entities were assigned attributes, primary keys and foreign keys were defined and the data types for each was assigned. For example; the data types of primary keys for the project ID entities were selected as short text indicating the letters (PIL) and followed by the project number, however in the time dimension the primary keys were set to be assigned automatically by the DBMS. The keys for work types, activities, and items followed the standard coding practice in the company with the replacement of dots with underscores to make the data field in accordance with the DBMS standards.

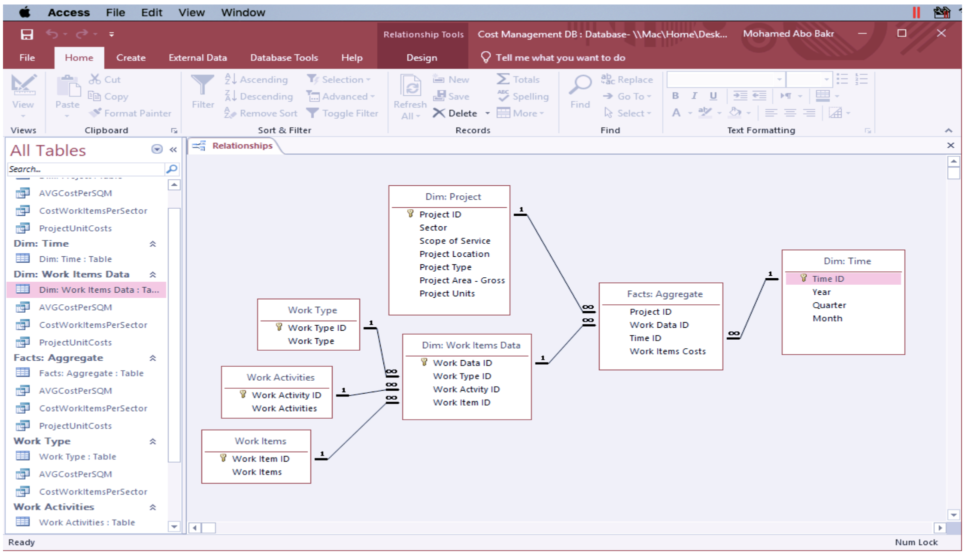


Figure 20 – Cost Data Warehouse Physical Model

Source; Own Elaboration

4.8 Loading of Data into the Physical Model

4.8.1 Data Preparation

The data provided by the company was extracted from its native form in the spreadsheets and manipulated to suit the logical design of the data warehouse. The work items, activities and types were abstracted from the generic view covering all items, activities and types and costs for each pilot project were aggregated in accordance with the level of the sheet. The codes assigned to each item were then converted into a short text rather than number format to be suitable for data types in the physical model; however, the format of the coding structure was respected for indexing in the same manner that was followed, not to cause any confusion to users. The data was aggregated through a number of spreadsheet operations, using look up functions and sorting as per the tabular design in the DBMS. The work items, activities and types were extracted and loaded into the corresponding tables in the DBMS. The project and time data were manually loaded into the project and time dimension tables and the data was cross checked for inconsistencies, duplicate entries or errors before loading the total costs into the facts table. The costs were loaded into the central facts table in correspondence with each of the foreign keys from each dimension. The physical model of the data warehouse was now ready for queries and OLAP analysis. Also, an important function of the data warehouse was the ability to export data to a spreadsheet and perform pivot analysis using Microsoft SQL Query.

Relationships | Dim: Project

Project ID	Sector	Scope of Service	Project Loca	Project Type	Project Area	Project Units	Click to Add
PIL01	Commercial	Cost Management	120 00	Refurbishment	6569	47	
PIL02	Residential	Cost Managemen	460 10	New Building	1945	18	
PIL03	Commercial	Project Management	625 00	New Building	12546	178	
PIL04	Commercial	Project Management	779 00	Extension	1478	13	
PIL05	Mixed Use	Quality Management	865 83	Extension	4594	35	
					0	0	

Figure 21- Project Dimension Table

Source; Own Elaboration.

Basic queries were performed on the model to calculate the total costs for each project to verify the data accuracy against the provided spreadsheets. Some advanced queries were performed to analyse the total costs according to the number of units or per square meter of each project. Also, queries to calculate the average costs on the level of work types or work activities for different project types. This type of analytical calculation satisfied the company management and senior engineers' requirement as similar benchmarking activities were much more complex and time consuming when performed using spreadsheets.

4.8.2 Aggregate Functions and Queries Performed in The Data Warehouse

A number of aggregate functions were computed through queries in the Data warehouse, firstly to check the functionality of the data warehouse then to compute the average item costs per functional units or per square meter of the gross floor area. As an example, the maximum work items.

AVGCostPerSQM

Work Type	MaxOfWork Items	CostPerSQM
CONTINGENCIES (RISKS)	0.00 Kč	$0.00
EXTERNAL WORKS	1 202 000.00 Kč	$15.60
FACILITATING WORKS	0.00 Kč	$0.00
FINISHES	1 160 499.52 Kč	$68.82
FITTINGS	1 223 974.26 Kč	$24.66
MAIN CONTRACTOR'S OVERHEADS AND PROFITS	0.00 Kč	$0.00
MAIN CONTRACTOR'S PRELIMINARIES	3 456 678.00 Kč	$28.77
OTHER DEVELOPMENT/PROJECT COSTS	1 249 574.00 Kč	$7.66
PREFABRICATED BUILDING	0.00 Kč	$0.00
PROJECT/DESIGN TEAM FEES	674 009.00 Kč	$7.29
SERVICES	9 152 060.77 Kč	$58.91
SUBSTRUCTURE	6 646 245.00 Kč	$217.25
SUPERSTRUCTURE	21 524 484.62 Kč	$247.92
WORK TO EXISTING BUILDING	0.00 Kč	$0.00

Figure 22 – Table view of the results of Query Average Costs per Square Meter of GFA For PIL03

Source; own Elaboration.

The aggregate functions showed that the Data warehouse was operating as required and it returned the same results as those provided in the costs overview. Queries preformed were enter parameter value queries and queries to calculate project cost per unit.

ProjectUnitCosts

Project ID	AvgOfWork	Work Actvity ID	CostPerUnit
PIL04	0.00 Kč	0_1	$0.00
PIL04	197 287.50 Kč	0_2	$15 175.96
PIL04	186 795.00 Kč	0_3	$14 368.85
PIL04	0.00 Kč	0_4	$0.00
PIL04	166 320.00 Kč	0_5	$12 793.85
PIL04	0.00 Kč	0_6	$0.00
PIL04	532 146.80 Kč	1_1	$40 934.37
PIL04	0.00 Kč	10_1	$0.00
PIL04	0.00 Kč	10_2	$0.00
PIL04	171 198.00 Kč	11_1	$13 169.08
PIL04	0.00 Kč	11_2	$0.00
PIL04	98 994.00 Kč	11_3	$7 614.92
PIL04	0.00 Kč	12_1	$0.00
PIL04	0.00 Kč	13_1	$0.00
PIL04	0.00 Kč	13_2	$0.00
PIL04	480 000.00 Kč	13_3	$36 923.08
PIL04	490 000.00 Kč	13_4	$37 692.31
PIL04	149 760.00 Kč	2_1	$11 520.00
PIL04	99 601.67 Kč	2_2	$7 661.67
PIL04	141 920.00 Kč	2_3	$10 916.92
PIL04	132 642.50 Kč	2_4	$10 203.27
PIL04	100 491.67 Kč	2_5	$7 730.13
PIL04	116 050.00 Kč	2_6	$8 926.92
PIL04	110 001.50 Kč	2_7	$8 461.65
PIL04	106 200.00 Kč	2_8	$8 169.23
PIL04	105 000.00 Kč	3_1	$8 076.92
PIL04	101 920.00 Kč	3_2	$7 840.00
PIL04	99 513.67 Kč	3_3	$7 654.90
PIL04	71 218.13 Kč	4_1	$5 478.32

Record: 1 of 55 No Filter Search

Figure 23- Results of Average Costs per Project Units Query

Source; Own elaboration.

The SQL code for the queries shows many joins on different tables. due to aggregation of the cost data from multiple tables and also due to the high normalization of the data.

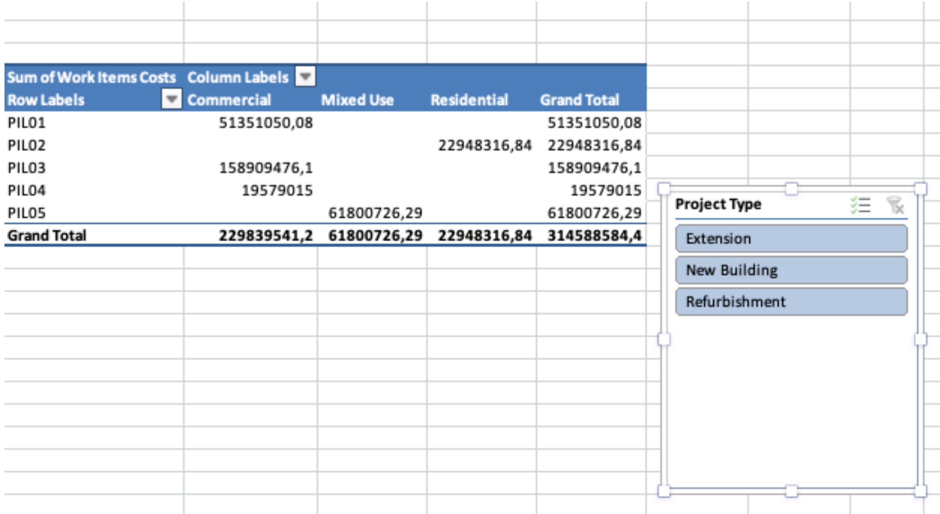
Table 8 – SQL Code for Enter Parameter Value Query

```
SELECT [Work Type].[Work Type], Max([Facts: Aggregate].[Work Items Costs]) AS [MaxOfWork Items Costs], Avg([Work Items Costs]/[Project Area – Gross Floor Area]) AS CostPerSQM

FROM [Work Type] INNER JOIN ([Dim: Work Items Data] INNER JOIN ([Dim: Project] INNER JOIN [Facts: Aggregate] ON [Dim: Project].[Project ID] = [Facts: Aggregate].[Project ID]) ON [Dim: Work Items Data].[Work Data ID] = [Facts: Aggregate].[Work Data ID]) ON [Work Type].[Work Type ID] = [Dim: Work Items Data].[Work Type ID]

WHERE ((([Facts: Aggregate].[Project ID])=[enter project id]))GROUP BY [Work Type].[Work Type], [Dim: Project].[Project Area – Gross Floor Area];
```

Source; own elaboration.

4.8.3 Further Data Analysis tools; Pivot Analysis

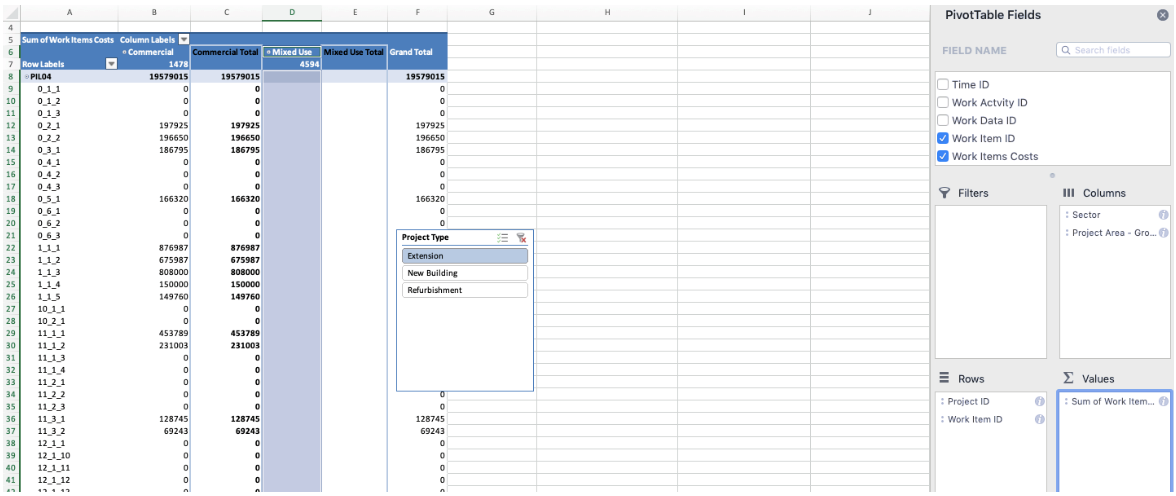
Data was extracted to spreadsheet through Microsoft SQL, which enabled the pivoting of data and grouping as required, it offered a high-quality pivot table for functions of pivot analysis and also offered much insight about the data. The slicing function works as a filter for data sets across levels. Figures 24 and 25 show the data structure in the pivot table and pivot analysis results.



Sum of Work Items Costs	Column Labels			
Row Labels	Commercial	Mixed Use	Residential	Grand Total
PIL01	51351050,08			51351050,08
PIL02			22948316,84	22948316,84
PIL03	158909476,1			158909476,1
PIL04	19579015			19579015
PIL05		61800726,29		61800726,29
Grand Total	229839541,2	61800726,29	22948316,84	314588584,4

Figure 24 - Pivot Analysis Functions of Extracted Data from the data warehouse

Source; Own elaboration.



Sum of Work Items Costs	Column Labels				
	Commercial	Commercial Total	Mixed Use	Mixed Use Total	Grand Total
Row Labels	1478		4594		
PIL04	19579015	19579015			19579015
0_1_1	0	0			0
0_1_2	0	0			0
0_1_3	0	0			0
0_2_1	197925	197925			197925
0_2_2	196650	196650			196650
0_3_1	186795	186795			186795
0_4_1	0	0			0
0_4_2	0	0			0
0_4_3	0	0			0
0_5_1	166320	166320			166320
0_6_1	0	0			0
0_6_2	0	0			0
0_6_3	0	0			
1_1_1	876987	876987			
1_1_2	675987	675987			
1_1_3	808000	808000			
1_1_4	150000	150000			
1_1_5	149760	149760			
10_1_1	0	0			
10_2_1	0	0			
11_1_1	453789	453789			
11_1_2	231003	231003			
11_1_3	0	0			
11_1_4	0	0			
11_2_1	0	0			
11_2_2	0	0			0
11_2_3	0	0			0
11_3_1	128745	128745			128745
11_3_2	69243	69243			69243
12_1_1	0	0			0
12_1_10	0	0			0
12_1_11	0	0			0
12_1_12	0	0			0

Figure 25 - Pivot Analysis by of Costs by Work Item Sliced according to Project type.

Source; Own elaboration

5. Discussion of The Study results

This chapter discusses the study results, highlights the conclusion and suggests further research related to this topic, and displays further applications for the Data warehouse model. it consists of the following titles;

- Discussion of Study results,
- Conclusions and Further applications of the data warehouse model.

This study was aimed at creating a physical data warehouse for the costs of work items of five pilot projects as provided by the company. The study has succeeded in creating a fully functional Data warehouse, ready for utilization and further incorporation of other projects. The Data warehouse creation had two objectives; the reduction of the process of preparation of a cost report and the utilization of the created Data warehouse to support management decisions by creating advanced analysis of costs data. In the vicinity of the scope of data given, being the five pilot project costs and work items, activities and types structure, the study has succeeded in creating what would become a baseline for future utilization within the company.

One of the advantages of the Data warehouse solution adopted is that the project data is directly stored in the data base, so the time required to extract, load and transform (ETL) the data stored in multiple spreadsheets is eliminated. Aggregate functions and queries permit detailed data analysis which is not permitted when storing project data in different spreadsheets. Moreover, crucial OLAP operations such as pivot analysis is also enabled with the construction data warehouse solution. Finally, the analytical reports exported by the provided solution can support predictive decision making based on data mining tools, namely classification and regression models.

This study utilized the BPMN diagrams for the depiction of current and future processes in the company. BPMN utilization in the study occurred as BPMN diagrams are an efficient method to depict business process flows. This study used the concept of Data warehousing due to its advantages in OLAP operations and aggregate query functions. The snow flake schema design was followed in the logical method due to its ability to consolidate data into a set of tables that are split for normalization and reduction of data redundancy.

6.Conclusions – Implications for Future Application

Based on the results obtained from this study it is concluded that the application of business intelligence tools and techniques is imperative to the construction cost estimation function. It also has improved the process of cost reporting significantly and provided management with insights to the historical project data which allows management to draw market trends and identify strategies. One prospect extension for the data warehouse is its application in transforming item costs different classification systems. This can be done by designing a data warehouse where the items are linked to indexes from each corresponding classification system.

Also, the applications of MS Queries, Pivot analysis and aggregate functions can be expanded upon and design of separate data marts for other functions in the company portfolio is a future expansion possibility.

The company management are ready to implement the Data warehouse in a beta mode for testing purposes and to practically measure the economic impact of the process reduction and business insight that the data warehouse would render. The aggregate functions achieved from this study are imperative for the benchmarking and cost estimation of future projects. The accuracy of the reports issued by the company have a direct influence on the market stance of the company and its overall rapport.

The Data warehouse needs further development and optimization to allow for multiple functions within the company portfolio; however, the data warehouse has achieved the required targets as per the input data, the scope of the target objectives and the potential for further implementation and expansion. Further research can be attempted in the domain of de-normalization to enable the performance of complex queries required in the application of payment certificates and variation orders. The data warehouse can also be extended to include a change management function.

Another possibility is the incorporation of the Data warehouse model in the process of interim payment certificate calculation in monthly payment of contractors' fees. This is another scope of service provided by the company that could greatly benefit from the automation of the aggregate functions. Furthermore, OLAP reports can be used for further, more advanced predicative decisions based on data mining techniques.

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7. List of Appendices

APPENDIX A Pilot Projects Information Sheets
APPENDIX B Pilot Projects Costs Sheets

APPENDIX A - *Pilot Projects Information Sheets*

Project Reference: PILOT 1

Project Name:

Location:

Country:	CZ
Region:	C. R. P.
City:	Prague
Postal Code:	120 00

Sector:

- [x] Commercial
- [ ] Residential
- [ ] Mixed Use
- [ ] Industrial

Client: Non-Disclosure

Project Type:

- [ ] New building
- [ ] Extension
- [x] Refurbishment

Project value: 51 351 050 Kč

GFA: 6 569 m2

Project Service:

- [ ] Project Management (PM)
- [x] Cost Management (CM)
- [ ] Quality Management (QM)

Publicity:

- [x] NDA
- [ ] Reference letter

Project description:

Refurbishment of exsiting commercial building in Prague, Czech Republic with the area (GFA) of 6 569 SQM and a Value of cca 32M Kč

The scopeof services on this project is Cost Management

Project Team:

Client:	Non-Disclosure
Supervisor:	Non-Disclosure
Project Manager:	Non-Disclosure
Design Manager:	Non-Disclosure
Cost Manager:	Non-Disclosure
Conceptual Architect:	Non-Disclosure
Designer:	Non-Disclosure
General Contractor:	Non-Disclosure

Other Project Particulars:

Stage of first involvement on project:

- [ ] Project set-up phase
- [x] Pre-tender phase
- [ ] Pre-construction phase
- [ ] Construction phase
- [ ] Post-construction phase

Project specific issues:

Project Reference: PILOT 2

Project Name:

Location:	Country: CZ Region: L. R. City: Liberec Postal Code: 460 10	**Sector:**	☐ Commercial ■ Residential ☐ Mixed Use ☐ Industrial
Client:	Non-Disclosure		
Project Type:	■ New building ☐ Extension ☐ Refurbishment	**Project Service:**	☐ Project Management (PM) ■ Cost Management (CM) ☐ Quality Management (QM)
Project value:	22 948 317 Kč		
GFA:	1 945 m2	**Publicity:**	■ NDA ☐ Reference letter

Project description:

New Build of Residential building in Liberec, Czech Republic with the area (GFA) of 1 945 SQM and a Value of cca 23M Kč

The scopeof services on this project is Cost Management

Project Team:

Client:	Non-Disclosure
Supervisor:	Non-Disclosure
Project Manager:	Non-Disclosure
Design Manager:	Non-Disclosure
Cost Manager:	Non-Disclosure
Conceptual Architect:	Non-Disclosure
Designer:	Non-Disclosure
General Contractor:	Non-Disclosure

Other Project Particulars:

Stage of first involvement on project:

- ☐ Project set-up phase
- ■ Pre-tender phase
- ☐ Pre-construction phase
- ☐ Construction phase
- ☐ Post-construction phase

Project specific issues:

Project Reference: PILOT 3		**Project Name:**	
Location: Country: CZ Region: S. M. R. City: Brno Postal Code: 625 00	**Sector:** ■ Commercial □ Residential □ Mixed Use □ Industrial **Client:** Non-Disclosure	**Project Type:** ■ New building □ Extension □ Refurbishment **Project value:** 158 909 476 Kč **GFA:** 12 546 m2	**Project Service:** ■ Project Management (PM) □ Cost Management (CM) □ Quality Management (QM) **Publicity:** ■ NDA □ Reference letter

Project description:
New Build of Commercial building in Brno, Czech Republic with the area (GFA) of 12 546 SQM and a Value of cca 159M Kč
The scopeof services on this project is Project Management

Project Team: Client: Non-Disclosure Supervisor: Non-Disclosure Project Manager: Non-Disclosure Design Manager: Non-Disclosure Cost Manager: Non-Disclosure Conceptual Architect: Non-Disclosure Designer: Non-Disclosure General Contractor: Non-Disclosure	**Other Project Particulars:** Stage of first involvement on project: □ Project set-up phase ■ Pre-tender phase □ Pre-construction phase □ Construction phase □ Post-construction phase	**Project specific issues:**

Project Reference: PILOT 4

Project Name:

Location:

Country:	CZ
Region:	M. R
City:	Olumouc
Postal Code:	779 00

Sector:

- [x] Commercial
- [ ] Residential
- [ ] Mixed Use
- [ ] Industrial

Client: Non-Disclosure

Project Type:

- [ ] New building
- [x] Extension
- [ ] Refurbishment

Project value: 19 579 015 Kč

GFA: 1 478 m2

Project Service:

- [x] Project Management (PM)
- [ ] Cost Management (CM)
- [ ] Quality Management (QM)

Publicity:

- [x] NDA
- [ ] Reference letter

Project description:

Extension of Commercial building in Olomouc, Czech Republic with the area (GFA) of 19 546 SQM and a Value of cca 20M Kč

The scopeof services on this project is Project Management

Project Team:

Client:	Non-Disclosure
Supervisor:	Non-Disclosure
Project Manager:	Non-Disclosure
Design Manager:	Non-Disclosure
Cost Manager:	Non-Disclosure
Conceptual Architect:	Non-Disclosure
Designer:	Non-Disclosure
General Contractor:	Non-Disclosure

Other Project Particulars:

Stage of first involvement on project:

- [ ] Project set-up phase
- [x] Pre-tender phase
- [ ] Pre-construction phase
- [ ] Construction phase
- [ ] Post-construction phase

Project specific issues:

Project Reference: PILOT 5

Project Name:

Location:
Country: SL
Region: B. R
City: Bratislava
Postal Code: 865 83

Sector:
□ Commercial
□ Residential
■ Mixed Use
□ Industrial

Client: Non-Disclosure

Project Type:
□ New building
■ Extension
□ Refurbishment

Project value: 61 800 726 Kč
GFA: 4 594 m^2

Project Service:
□ Project Management (PM)
□ Cost Management (CM)
■ Quality Management (QM)

Publicity:
■ NDA
□ Reference letter

Project description:
Extension of Mixed Use (Commercial + Residential) building in Bratislava, Slovak Republic with the area (GFA) of 4 594 SQM and a Value of cca 62M Kč
The scopeof services on this project is Project Management

Project Team:

Client:	Non-Disclosure
Supervisor:	Non-Disclosure
Project Manager:	Non-Disclosure
Design Manager:	Non-Disclosure
Cost Manager:	Non-Disclosure
Conceptual Architect:	Non-Disclosure
Designer:	Non-Disclosure
General Contractor:	Non-Disclosure

Other Project Particulars:
Stage of first involvement on project:
□ Project set-up phase
■ Pre-tender phase
□ Pre-construction phase
□ Construction phase
□ Post-construction phase

Project specific issues:

APPENDIX B - *Pilot Projects Costs Sheets*

Pilot Projects Cost Data						
Elemental - Level 1 - Group Elemental (Concise)						
Code	**Description**	**PIL.01**	**PIL.02**	**PIL.03**	**PIL.04**	**PIL.05**
0	**FACILITATING WORKS**	- CZK	89 382 CZK	- CZK	747 690 CZK	380 125 CZK
1	**SUBSTRUCTURE**	- CZK	872 337 CZK	13 628 299 CZK	2 660 734 CZK	8 174 585 CZK
2	**SUPERSTRUCTURE**	2 237 820 CZK	3 605 163 CZK	83 981 931 CZK	3 211 911 CZK	10 230 339 CZK
3	**FINISHES**	1 565 541 CZK	1 143 138 CZK	5 180 517 CZK	607 381 CZK	3 080 339 CZK
4	**FITTINGS**	857 506 CZK	890 575 CZK	2 474 586 CZK	569 745 CZK	1 678 245 CZK
5	**SERVICES**	7 802 514 CZK	5 139 344 CZK	39 174 064 CZK	4 593 628 CZK	26 323 838 CZK
6	**PREFABRICATED BUILDING**	- CZK	216 051 CZK	- CZK	75 750 CZK	59 067 CZK
7	**WORK TO EXISTING BUILDING**	2 204 610 CZK	421 310 CZK	- CZK	121 810 CZK	321 250 CZK
8	**EXTERNAL WORKS**	595 273 CZK	4 609 583 CZK	6 261 952 CZK	1 108 031 CZK	4 994 114 CZK
9	**MAIN CONTRACTOR'S PRELIMINARIES**	26 940 518 CZK	3 685 000 CZK	6 135 141 CZK	4 029 555 CZK	3 989 945 CZK
10	**MAIN CONTRACTOR'S OVERHEADS AND PROFITS**	- CZK	- CZK	- CZK	- CZK	- CZK
11	**PROJECT/DESIGN TEAM FEES**	516 090 CZK	1 306 434 CZK	823 412 CZK	882 780 CZK	513 349 CZK
12	**OTHER DEVELOPMENT/PROJECT COSTS**	- CZK	- CZK	1 249 574 CZK	- CZK	620 448 CZK
13	**CONTINGENCIES (RISKS)**	8 631 178 CZK	970 000 CZK	- CZK	970 000 CZK	1 435 082 CZK
	TOTAL FOR BUILDING	**51 351 050 Kč**	**22 948 317 Kč**	**158 909 476 Kč**	**19 579 015 Kč**	**61 800 726 Kč**

Pilot Projects Cost Data						
Elemental - Level 2 - Elemental (Detailed)						
Code	**Description**	**PIL.01**	**PIL.02**	**PIL.03**	**PIL.04**	**PIL.05**
0	**FACILITATING WORKS**	**0**	**89382**	**0**	**747690**	**380124,9833**
0_1	TOXIC/HAZARDOUS/CONTAMINATED MATERIAL TREATMENT	0	1200	0	0	119,1666667
0_2	MAJOR DEMOLITION WORK	0	33864	0	394575	199280,3313
0_3	TEMPORARY SUPPORTS TO ADJACENT STRUCTURES	0	3621	0	186795	93108,49167
0_4	SPECIALIST GROUNDWORKS	0	50697	0	0	5034,49375
0_5	TEMPORARY DIVERSION WORKS	0	0	0	166320	82582,5
0_6	EXTRAORDINARY SITE INVESTIGATION WORKS	0	0	0	0	0
1	**SUBSTRUCTURE**	**0**	**872337**	**13628299**	**2660734**	**8174585,268**
1_1	SUBSTRUCTURE	0	872337	13628299	2660734	8174585,268
2	**SUPERSTRUCTURE**	**2237819,77**	**3605163**	**83981930,65**	**3211911**	**10230338,59**
2_1	FRAME	0	627200	177756,3688	149760	224905,4192
2_2	UPPER FLOORS	114080	1301910	405703,9222	298805	490423,9232
2_3	ROOF	797568,7545	392700	28171352,5	851520	3220127,294
2_4	STAIRS AND RAMPS	176575,5821	239213	38758865,17	530570	1287024,507
2_5	EXTERNAL WALLS & EXTERIOR FINISH	625893,4336	251900	13300729,1	602950	2317963,1
2_6	WINDOWS AND EXTERNAL DOORS	100100	353500	1663088,384	232100	986058,6768
2_7	INTERNAL WALLS AND PARTITIONS	342402	342060	1363949,058	440006	963684,6752
2_8	INTERNAL DOORS	81200	96680	140486,1467	106200	740150,9964
3	**INTERNAL FINISHES**	**1565541**	**1143138**	**5180517**	**607381**	**3080339,005**
3_1	WALL FINISHES	264960	202500	1092620,475	105000	641073,208
3_2	FLOOR FINISHES	892800	375000	1502107,313	203840	972949,8118
3_3	CEILING FINISHES	407781	565638	2585789,212	298541	1466315,985
4	**FITTINGS, FURNISHINGS AND EQUIPMENT**	**857506,0766**	**890575**	**2474586,484**	**569745**	**1678244,865**
4_1	FITTINGS, FURNISHINGS AND EQUIPMENT	857506,0766	890575	2474586,484	569745	1678244,865
5	**SERVICES**	**7802513,729**	**5139344**	**39174063,84**	**4593628**	**26323838,27**
5_1	SANITARY INSTALLATIONS	240249,286	271970	9237794,96	167000	4720608,162
5_2	SERVICES EQUIPMENT	48939,66936	210000	2972146,963	82250	1542307,084
5_3	DISPOSAL INSTALLATIONS -SEWAGE	106777,4604	149760	23436,2843	81200	77430,41675
5_4	WATER INSTALLATIONS	158419,643	680665	3733237,694	478050	2080062,364
5_5	HEATING	32418	140000	523381,9417	74340	313907,6127
5_6	SPACE HEATING AND AIR CONDITIONING	988283,7865	1019080	1352344,623	546470	1142156,581
5_7	VENTILATION	70745,40641	350432	713744,9737	132900	1107694,115
5_8	ELECTRICAL INSTALLATIONS	423503,374	713472	7049573,111	350978	4276955,87
5_9	FUEL INSTALLATIONS	0	0	0	0	0
5_10	LIFT AND CONVEYOR INSTALLATIONS	1971357,103	622000	1802420,708	1667760	3198275,019
5_11	FIRE AND LIGHTNING PROTECTION	1686374	341445	4493591,35	312290	2964505,751
5_12	COMMUNICATION, SECURITY AND CONTROL SYSTEMS	1875318	251400	4055435,941	109840	2279370,119
5_13	SPECIALIST INSTALLATIONS	0	334000	3048370,288	560175	2496428,459
5_14	BUILDER'S WORK IN CONNECTION WITH SERVICES	200128	55120	168585,0051	30375	124136,7136
6	**PREFABRICATED BUILDINGS AND BUILDING UNITS**	**0**	**216051**	**0**	**75750**	**59067,04375**
6_1	PREFABRICATED BUILDINGS AND BUILDING UNITS	0	216051	0	75750	59067,04375
7	**WORK TO EXISTING BUILDINGS**	**2204610**	**421310**	**0**	**121810**	**321250,4931**
7_1	MINOR DEMOLITION AND ALTERATION WORKS	281600	74340	0	22125	46332,49653
7_2	REPAIRS TO EXISTING SERVISES	10585	72420	0	22000	19166,46875
7_3	DAMP PROOFCOURSES/FUNGUS ND BEETLE ERADICATION	931000	72000	0	20525	109794,7049
7_4	FAÇADE RETENTION	396000	67550	0	19360	55645,86806
7_5	CLEANING EXISTING SURFACES	116000	67500	0	18900	27606,94444
7_6	RENNOVATION WORKS	469425	67500	0	18900	62704,01042
8	**EXTERNAL WORKS**	**595273,3468**	**4609582,58**	**6261951,917**	**1108031**	**4994113,501**
8_1	SITE PREPARATION WORKS	350575	199500	556425	52740	357092,8472
8_2	ROADS, PATHS, PAVINGS AND SURFACINGS	0	125440	2133090	30500	1086739,424
8_3	SOFT LANDSCAPING, PLANTING AND IRRIGATION SYSTEMS	0	181260	1079700	36230	572090,3681
8_4	FENCING, RAILINGS AND WALLS	0	234000	512054	20200	1369945,396
8_5	EXTERNAL FIXTURES	0	48750	0	0	48411
8_6	EXTERNAL DRAINAGE	31143,42596	1430650	586500	64749	468527,427
8_7	EXTERNAL SERVICES	213554,9209	2389982,58	1394182,917	903612	1091307,039
8_8	MINOR BUILDING WORKS AND ANCILLARY BUILDINGS	0	0	0	0	0
9	**MAIN CONTRACTOR'S PRELIMINARIES**	**26940517,62**	**3685000**	**6135141**	**4029555**	**3989945,153**
9_1	EMPLOYER'S REQUIREMENTS	0	0	0	0	0
9_2	MAIN CONTRACTOR'S COST ITEMS	26940517,62	3685000	6135141	4029555	3989945,153
10	**MAIN CONTRACTOR'S OVERHEADS AND PROFITS**	**0**	**0**	**0**	**0**	**0**
10_1	MAIN CONTRACTOR'S OVERHEADS	0	0	0	0	0
10_2	MAIN CONTRACTOR'S PROFITS	0	0	0	0	0
11	**PROJECT/DESIGN TEAM FEES**	**516090,4872**	**1306434,26**	**823412,25**	**882780**	**513348,6545**
11_1	CONSULTANT'S FEES	516090,4872	1081434,26	823412,25	684792	392698,3629
11_2	MAIN CONTRACTOR'S PRE-CONSTRUCTION FEES	0	0	0	0	0
11_3	MAIN CONTRACTOR'S DESIGN FEES	0	225000	0	197988	120650,2917
12	**OTHER DEVELOPMENT/PROJECT COSTS**	**0**	**0**	**1249574**	**0**	**620448,2014**
12_1	OTHER DEVELOPMENT/PROJECT COSTS	0	0	1249574	0	620448,2014
13	**RISK (CLIENT'S CONTENGENCIES)**	**8631178,051**	**970000**	**0**	**970000**	**1435082,265**
13_1	DESIGN DEVELOPMENT RISKS	0	0	0	0	0
13_2	CONSTRUCTION RISKS	0	0	0	0	0
13_3	EMPLOYER CHANGE RISKS	4271098,417	480000	0	480000	710143,8011
13_4	EMPLOYER OTHER RISKS	4360079,634	490000	0	490000	724938,4637
	TOTAL FOR BUILDING	**51351050,08**	**22948316,84**	**158909476,1**	**19579015**	**61800726,29**

Pilot Projects Cost Data					
Elemental - Level 3 - Sub-elemental (Amplified)					
Code	**Description**	**PIL.01**	**PIL.02**	**PIL.03**	**PIL.04**
0_1	**TOXIC/HAZARDOUS/CONTAMINATED MATERIAL TREATMENT**	**0 Kč**	**1 200 Kč**	**0 Kč**	**0 Kč**
0_1_1	Toxic/Hazardous Material Removal	0 Kč	0 Kč	0 Kč	0 Kč
0_1_2	Contaminated Land	0 Kč	0 Kč	0 Kč	0 Kč
0_1_3	Eradication of Plant Growth	0 Kč	1 200 Kč	0 Kč	0 Kč
0_2	**MAJOR DEMOLITION WORK**	**0 Kč**	**33 864 Kč**	**0 Kč**	**394 575 Kč**
0_2_1	Demolition Works	0 Kč	8 000 Kč	0 Kč	197 925 Kč
0_2_2	Soft Strip Works	0 Kč	25 864 Kč	0 Kč	196 650 Kč
0_3	**TEMPORARY SUPPORTS TO ADJACENT STRUCTURES**	**0 Kč**	**3 621 Kč**	**0 Kč**	**186 795 Kč**
0_3_1	Temporary Supports to Adjacent Structures	0 Kč	3 621 Kč	0 Kč	186 795 Kč
0_4	**SPECIALIST GROUNDWORKS**	**0 Kč**	**50 697 Kč**	**0 Kč**	**0 Kč**
0_4_1	Site Dewatering and Pumping	0 Kč	16 899 Kč	0 Kč	0 Kč
0_4_2	Soil Stabilisation Measures	0 Kč	16 899 Kč	0 Kč	0 Kč
0_4_3	Ground Gas Venting Measures	0 Kč	16 899 Kč	0 Kč	0 Kč
0_5	**TEMPORARY DIVERSION WORKS**	**0 Kč**	**0 Kč**	**0 Kč**	**166 320 Kč**
0_5_1	Temporary Diversion Works	0 Kč	0 Kč	0 Kč	166 320 Kč
0_6	**EXTRAORDINARY SITE INVESTIGATION WORKS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
0_6_1	Archaeological Investigation	0 Kč	0 Kč	0 Kč	0 Kč
0_6_2	Reptile/Wildlife Mitigation Measures	0 Kč	0 Kč	0 Kč	0 Kč
0_6_3	Other Extraordinary Site Investigation Works	0 Kč	0 Kč	0 Kč	0 Kč
1_1	**SUBSTRUCTURE**	**0 Kč**	**872 337 Kč**	**13 628 299 Kč**	**2 660 734 Kč**
1_1_1	Standard Foundations	0 Kč	310 368 Kč	2 741 984 Kč	876 987 Kč
1_1_2	Specialist Foundations	0 Kč	289 680 Kč	6 646 245 Kč	675 987 Kč
1_1_3	Lowest Floor Construction	0 Kč	185 889 Kč	1 277 650 Kč	808 000 Kč
1_1_4	Basement Excavation	0 Kč	86 400 Kč	2 962 420 Kč	150 000 Kč
1_1_5	Basement Retaining Walls	0 Kč	0 Kč	0 Kč	149 760 Kč
2_1	**FRAME**	**0 Kč**	**627 200 Kč**	**177 756 Kč**	**149 760 Kč**
2_1_1	Frame	0 Kč	627 200 Kč	177 756 Kč	149 760 Kč
2_2	**UPPER FLOORS**	**114 080 Kč**	**1 301 910 Kč**	**405 704 Kč**	**298 805 Kč**
2_2_1	Floors	0 Kč	752 000 Kč	48 543 Kč	149 600 Kč
2_2_2	Balconies	0 Kč	125 060 Kč	0 Kč	0 Kč
2_2_3	Drainage to Balconies	114 080 Kč	424 850 Kč	357 161 Kč	149 205 Kč
2_3	**ROOF**	**797 569 Kč**	**392 700 Kč**	**28 171 353 Kč**	**851 520 Kč**
2_3_1	Roof Structure	0 Kč	135 000 Kč	335 703 Kč	147 936 Kč
2_3_2	Roof Coverings	293 638 Kč	33 000 Kč	6 252 971 Kč	144 000 Kč
2_3_3	Specialist Roof Systems	264 960 Kč	97 200 Kč	547 896 Kč	143 624 Kč
2_3_4	Roof Drainage	200 208 Kč	22 500 Kč	8 164 921 Kč	140 000 Kč
2_3_5	Roof Lights, Skylights and Openings	38 763 Kč	67 500 Kč	12 320 459 Kč	139 560 Kč
2_3_6	Roof Features	0 Kč	37 500 Kč	549 401 Kč	136 400 Kč
2_4	**STAIRS AND RAMPS**	**176 576 Kč**	**239 213 Kč**	**38 758 865 Kč**	**530 570 Kč**
2_4_1	Stair/Ramp Structures	0 Kč	67 200 Kč	14 075 307 Kč	135 000 Kč
2_4_2	Stair/Ramp Finishes	48 940 Kč	64 000 Kč	21 524 485 Kč	133 510 Kč
2_4_3	Stair/Ramp Balustrades and Handrails	60 900 Kč	75 130 Kč	49 839 Kč	132 060 Kč
2_4_4	Ladders/Chutes/Slides	66 736 Kč	32 883 Kč	3 109 234 Kč	130 000 Kč
2_5	**EXTERNAL WALLS & EXTERIOR FINISH**	**625 893 Kč**	**251 900 Kč**	**13 300 729 Kč**	**602 950 Kč**
2_5_1	External Enclosing Walls above ground level	0 Kč	40 600 Kč	3 010 417 Kč	125 060 Kč
2_5_2	External Enclosing Walls below ground level	0 Kč	0 Kč	8 405 085 Kč	120 000 Kč
2_5_3	Solar/Rain Screening	22 245 Kč	0 Kč	100 882 Kč	120 000 Kč
2_5_4	External Soffits	0 Kč	136 500 Kč	0 Kč	0 Kč
2_5_5	Subsidiary Walls, Balustrades and Proprietary Balconies	66 558 Kč	74 800 Kč	922 103 Kč	119 200 Kč
2_5_6	Façade Access/Cleaning Systems	537 091 Kč	0 Kč	862 241 Kč	118 690 Kč
2_6	**WINDOWS AND EXTERNAL DOORS**	**100 100 Kč**	**353 500 Kč**	**1 663 088 Kč**	**232 100 Kč**
2_6_1	External Windows	81 200 Kč	315 000 Kč	314 421 Kč	116 100 Kč
2_6_2	External Doors	18 900 Kč	38 500 Kč	1 348 667 Kč	116 000 Kč
2_7	**INTERNAL WALLS AND PARTITIONS**	**342 402 Kč**	**342 060 Kč**	**1 363 949 Kč**	**440 006 Kč**
2_7_1	Walls and Partitions	82 676 Kč	20 740 Kč	1 080 405 Kč	114 080 Kč
2_7_2	Balustrades and Handrails	21 510 Kč	165 900 Kč	0 Kč	112 770 Kč
2_7_3	Moveable Room Dividers	88 456 Kč	83 000 Kč	146 402 Kč	106 656 Kč
2_7_4	Cubicles	149 760 Kč	72 420 Kč	137 141 Kč	106 500 Kč
2_8	**INTERNAL DOORS**	**81 200 Kč**	**96 680 Kč**	**140 486 Kč**	**106 200 Kč**
2_8_1	Doors	81 200 Kč	96 680 Kč	140 486 Kč	106 200 Kč
3_1	**WALL FINISHES**	**264 960 Kč**	**202 500 Kč**	**1 092 620 Kč**	**105 000 Kč**
3_1_1	Finishes to Walls	264 960 Kč	202 500 Kč	1 092 620 Kč	105 000 Kč
3_2	**FLOOR FINISHES**	**892 800 Kč**	**375 000 Kč**	**1 502 107 Kč**	**203 840 Kč**
3_2_1	Finishes to Floors	652 800 Kč	202 500 Kč	341 608 Kč	103 400 Kč
3_2_2	Raised Access Floors	240 000 Kč	172 500 Kč	1 160 500 Kč	100 440 Kč
3_3	**CEILING FINISHES**	**407 781 Kč**	**565 638 Kč**	**2 585 789 Kč**	**298 541 Kč**
3_3_1	Finishes to Ceilings	307 200 Kč	197 925 Kč	786 687 Kč	100 100 Kč
3_3_2	False Ceilings	38 295 Kč	180 918 Kč	923 033 Kč	99 625 Kč
3_3_3	Demountable Suspended Ceilings	62 286 Kč	186 795 Kč	876 070 Kč	98 816 Kč
4_1	**FITTINGS, FURNISHINGS AND EQUIPMENT**	**857 506 Kč**	**890 575 Kč**	**2 474 586 Kč**	**569 745 Kč**
4_1_1	General Fittings, Furnishings and Equipment	307 200 Kč	180 000 Kč	247 596 Kč	98 520 Kč
4_1_2	Domestic Kitchen Fittings and Equipment	100 100 Kč	175 000 Kč	371 106 Kč	97 500 Kč
4_1_3	Special Purpose Fittings, Furnishings and Equipment	400 415 Kč	173 200 Kč	445 630 Kč	97 200 Kč
4_1_4	Signs/Notices	5 300 Kč	103 950 Kč	88 362 Kč	96 680 Kč
4_1_5	Works of Art	0 Kč	0 Kč	0 Kč	0 Kč
4_1_6	Non-Mechanical and Non-Electrical Equipment	0 Kč	97 125 Kč	1 223 974 Kč	93 445 Kč
4_1_7	Internal Planting	44 491 Kč	161 300 Kč	97 918 Kč	86 400 Kč

Pilot Projects Cost Data					
Elemental - Level 3 - Sub-elemental (Amplified)					
Code	**Description**	**PIL.01**	**PIL.02**	**PIL.03**	**PIL.04**
4_1_8	Bird and Vermin Control	0 Kč	0 Kč	0 Kč	0 Kč
5_1	**SANITARY INSTALLATIONS**	**240 249 Kč**	**271 970 Kč**	**9 237 795 Kč**	**167 000 Kč**
5_1_1	Sanitary Appliances	173 513 Kč	119 970 Kč	85 734 Kč	84 000 Kč
5_1_2	Sanitary Ancillaries	66 736 Kč	152 000 Kč	9 152 061 Kč	83 000 Kč
5_2	**SERVICES EQUIPMENT**	**48 940 Kč**	**210 000 Kč**	**2 972 147 Kč**	**82 250 Kč**
5_2_1	Service Equipment	48 940 Kč	210 000 Kč	2 972 147 Kč	82 250 Kč
5_3	**DISPOSAL INSTALLATIONS -SEWAGE**	**106 777 Kč**	**149 760 Kč**	**23 436 Kč**	**81 200 Kč**
5_3_1	Foul Drainage above ground	106 777 Kč	149 760 Kč	23 436 Kč	81 200 Kč
5_3_2	Chemical, Toxic and Industrial Liquid Waste Drainage	0 Kč	0 Kč	0 Kč	0 Kč
5_3_3	Refuse Disposal	0 Kč	0 Kč	0 Kč	0 Kč
5_4	**WATER INSTALLATIONS**	**158 420 Kč**	**680 665 Kč**	**3 733 238 Kč**	**478 050 Kč**
5_4_1	Mains Water Supply	0 Kč	139 520 Kč	149 961 Kč	176 800 Kč
5_4_2	Cold Water Distribution	48 940 Kč	128 625 Kč	878 343 Kč	76 320 Kč
5_4_3	Hot Water Distribution	48 940 Kč	147 936 Kč	789 022 Kč	75 130 Kč
5_4_4	Local Hot Water Distribution	22 245 Kč	120 960 Kč	984 324 Kč	75 000 Kč
5_4_5	Steam and Condensate Distribution	38 295 Kč	143 624 Kč	931 588 Kč	74 800 Kč
5_5	**HEATING**	**32 418 Kč**	**140 000 Kč**	**523 382 Kč**	**74 340 Kč**
5_5_1	Heat Source	32 418 Kč	140 000 Kč	523 382 Kč	74 340 Kč
5_6	**SPACE HEATING AND AIR CONDITIONING**	**988 284 Kč**	**1 019 080 Kč**	**1 352 345 Kč**	**546 470 Kč**
5_6_1	Central Heating	97 879 Kč	139 560 Kč	146 867 Kč	72 420 Kč
5_6_2	Local Heating	106 777 Kč	118 800 Kč	93 745 Kč	72 000 Kč
5_6_3	Central Cooling	17 796 Kč	135 000 Kč	102 267 Kč	67 550 Kč
5_6_4	Local Cooling	35 595 Kč	133 510 Kč	690 305 Kč	67 500 Kč
5_6_5	Central Heating and Cooling	563 841 Kč	117 150 Kč	138 061 Kč	67 500 Kč
5_6_6	Local Heating and Cooling	100 104 Kč	130 000 Kč	31 959 Kč	67 200 Kč
5_6_7	Central Air Conditioning	55 613 Kč	125 060 Kč	95 876 Kč	66 300 Kč
5_6_8	Local Air Conditioning	10 678 Kč	120 000 Kč	53 264 Kč	66 000 Kč
5_7	**VENTILATION**	**70 745 Kč**	**350 432 Kč**	**713 745 Kč**	**132 900 Kč**
5_7_1	Central Ventilation	48 940 Kč	120 000 Kč	95 450 Kč	8 000 Kč
5_7_2	Local and Special Ventilation	10 678 Kč	116 000 Kč	106 958 Kč	64 000 Kč
5_7_3	Smoke Extract/Control	11 128 Kč	114 432 Kč	511 337 Kč	60 900 Kč
5_8	**ELECTRICAL INSTALLATIONS**	**423 503 Kč**	**713 472 Kč**	**7 049 573 Kč**	**350 978 Kč**
5_8_1	Electric Mains and Sub-mains Distribution	0 Kč	118 690 Kč	704 457 Kč	60 360 Kč
5_8_2	Power Installations	15 572 Kč	116 100 Kč	463 612 Kč	60 000 Kč
5_8_3	Lighting Installations	71 185 Kč	92 800 Kč	2 736 719 Kč	57 200 Kč
5_8_4	Specialist Lighting Installations	4 583 Kč	101 200 Kč	1 749 909 Kč	56 320 Kč
5_8_5	Local Electricity Generation Systems	248 160 Kč	218 022 Kč	1 338 638 Kč	50 000 Kč
5_8_6	Earthing and Bonding Systems	84 004 Kč	66 660 Kč	56 238 Kč	67 098 Kč
5_9	**FUEL INSTALLATIONS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
5_9_1	Fuel Storage	0 Kč	0 Kč	0 Kč	0 Kč
5_9_2	Fuel Distribution Systems	0 Kč	0 Kč	0 Kč	0 Kč
5_10	**LIFT AND CONVEYOR INSTALLATIONS**	**1 971 357 Kč**	**622 000 Kč**	**1 802 421 Kč**	**1 667 760 Kč**
5_10_1	Lifts and Enclosed Hoists	897 675 Kč	105 000 Kč	142 663 Kč	43 750 Kč
5_10_2	Escalators	111 227 Kč	517 000 Kč	17 045 Kč	42 480 Kč
5_10_3	Moving Pavements	0 Kč	0 Kč	0 Kč	0 Kč
5_10_4	Powered Stairlifts	100 100 Kč	0 Kč	284 218 Kč	40 600 Kč
5_10_5	Conveyors	765 676 Kč	0 Kč	1 262 619 Kč	1 402 530 Kč
5_10_6	Dock Levellers and Scissor Lifts	0 Kč	0 Kč	0 Kč	0 Kč
5_10_7	Cranes and Unenclosed Hoists	0 Kč	0 Kč	0 Kč	0 Kč
5_10_8	Car Lifts, Car Stacking Systems, Turntables and the like	0 Kč	0 Kč	0 Kč	0 Kč
5_10_9	Document Handling Systems	0 Kč	0 Kč	0 Kč	0 Kč
5_10_10	Other Lift and Conveyor Installations	96 680 Kč	0 Kč	95 876 Kč	138 400 Kč
5_11	**FIRE AND LIGHTNING PROTECTION**	**1 686 374 Kč**	**341 445 Kč**	**4 493 591 Kč**	**312 290 Kč**
5_11_1	Fire fighting Systems	587 264 Kč	146 600 Kč	922 431 Kč	137 500 Kč
5_11_2	Fire Suppression Systems	966 804 Kč	108 445 Kč	1 426 229 Kč	137 500 Kč
5_11_3	Lightning Protection	132 306 Kč	86 400 Kč	2 144 931 Kč	37 290 Kč
5_12	**COMMUNICATION, SECURITY AND CONTROL SYSTEMS**	**1 875 318 Kč**	**251 400 Kč**	**4 055 436 Kč**	**109 840 Kč**
5_12_1	Communication Systems	822 509 Kč	84 400 Kč	839 956 Kč	37 290 Kč
5_12_2	Security Systems	760 009 Kč	84 000 Kč	534 369 Kč	36 300 Kč
5_12_3	Central Control/Building Management Systems	292 800 Kč	83 000 Kč	2 681 111 Kč	36 250 Kč
5_13	**SPECIALIST INSTALLATIONS**	**0 Kč**	**334 000 Kč**	**3 048 370 Kč**	**560 175 Kč**
5_13_1	Specialist Piped Supply Installations	0 Kč	82 250 Kč	60 338 Kč	33 425 Kč
5_13_2	Specialist Refrigeration Systems	0 Kč	0 Kč	638 026 Kč	433 000 Kč
5_13_3	Specialist Mechanical Installations	0 Kč	78 750 Kč	1 135 864 Kč	32 175 Kč
5_13_4	Specialist Electrical/Electronic Installations	0 Kč	77 000 Kč	151 271 Kč	31 200 Kč
5_13_5	Water Features	0 Kč	96 000 Kč	1 062 871 Kč	30 375 Kč
5_14	**BUILDER'S WORK IN CONNECTION WITH SERVICES**	**200 128 Kč**	**55 120 Kč**	**168 585 Kč**	**30 375 Kč**
5_14_1	Builder's Work in connection with services	200 128 Kč	55 120 Kč	168 585 Kč	30 375 Kč
6_1	**PREFABRICATED BUILDINGS AND BUILDING UNITS**	**0 Kč**	**216 051 Kč**	**0 Kč**	**75 750 Kč**
6_1_1	Complete Buildings	0 Kč	66 251 Kč	0 Kč	27 000 Kč
6_1_2	Building Units	0 Kč	75 000 Kč	0 Kč	26 250 Kč
6_1_3	Pods	0 Kč	74 800 Kč	0 Kč	22 500 Kč
7_1	**MINOR DEMOLITION AND ALTERATION WORKS**	**281 600 Kč**	**74 340 Kč**	**0 Kč**	**22 125 Kč**
7_1_1	Minor Demolition and Alteration Works	281 600 Kč	74 340 Kč	0 Kč	22 125 Kč
7_2	**REPAIRS TO EXISTING SERVICES**	**10 585 Kč**	**72 420 Kč**	**0 Kč**	**22 000 Kč**
7_2_1	Repairs to Existsing Services	10 585 Kč	72 420 Kč	0 Kč	22 000 Kč
7_3	**DAMP PROOFCOURSES/FUNGUS AND BEETLE ERADICATION**	**931 000 Kč**	**72 000 Kč**	**0 Kč**	**20 525 Kč**
7_3_1	Damp Proofcourses/Fungus and Beetle Eradication	931 000 Kč	72 000 Kč	0 Kč	20 525 Kč

Pilot Projects Cost Data					
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Code	**Description**	**PIL.01**	**PIL.02**	**PIL.03**	**PIL.04**
7_4	**FAÇADE RETENTION**	**396 000 Kč**	**67 550 Kč**	**0 Kč**	**19 360 Kč**
7_4_1	Façade retention	396 000 Kč	67 550 Kč	0 Kč	19 360 Kč
7_5	**CLEANING EXISTING SURFACES**	**116 000 Kč**	**67 500 Kč**	**0 Kč**	**18 900 Kč**
7_5_1	Façade retention	116 000 Kč	67 500 Kč	0 Kč	18 900 Kč
7_6	**RENNOVATION WORKS**	**469 425 Kč**	**67 500 Kč**	**0 Kč**	**18 900 Kč**
7_6_1	Rennovation Works	469 425 Kč	67 500 Kč	0 Kč	18 900 Kč
8_1	**SITE PREPARATION WORKS**	**350 575 Kč**	**199 500 Kč**	**556 425 Kč**	**52 740 Kč**
8_1_1	Site Preparation Works	303 325 Kč	67 200 Kč	461 425 Kč	18 480 Kč
8_1_2	Site Clearance	47 250 Kč	66 300 Kč	95 000 Kč	17 760 Kč
8_1_3	Preparatory Groundworks	0 Kč	66 000 Kč	0 Kč	16 500 Kč
8_2	**ROADS, PATHS, PAVINGS AND SURFACINGS**	**0 Kč**	**125 440 Kč**	**2 133 090 Kč**	**30 500 Kč**
8_2_1	Roads, Paths and Pavings	0 Kč	64 000 Kč	931 090 Kč	16 500 Kč
8_2_2	Special Surfacing and Pavings	0 Kč	61 440 Kč	1 202 000 Kč	14 000 Kč
8_3	**SOFT LANDSCAPING, PLANTING AND IRRIGATION SYSTEMS**	**0 Kč**	**181 260 Kč**	**1 079 700 Kč**	**36 230 Kč**
8_3_1	Seeding and Turfing	0 Kč	60 900 Kč	0 Kč	13 230 Kč
8_3_2	External Planting	0 Kč	60 360 Kč	543 984 Kč	12 000 Kč
8_3_3	Irrigation Systems	0 Kč	60 000 Kč	535 716 Kč	11 000 Kč
8_4	**FENCING, RAILINGS AND WALLS**	**0 Kč**	**234 000 Kč**	**512 054 Kč**	**20 200 Kč**
8_4_1	Fencing and Railings	0 Kč	57 200 Kč	512 054 Kč	10 200 Kč
8_4_2	Walls and Screens	0 Kč	76 800 Kč	0 Kč	10 000 Kč
8_4_3	Retaining Walls	0 Kč	50 000 Kč	0 Kč	0 Kč
8_4_4	Barriers and Guardrails	0 Kč	50 000 Kč	0 Kč	0 Kč
8_5	**EXTERNAL FIXTURES**	**0 Kč**	**48 750 Kč**	**0 Kč**	**0 Kč**
8_5_1	Site/Street Furniture and Equipment	0 Kč	48 750 Kč	0 Kč	0 Kč
8_5_2	Ornamental Features	0 Kč	0 Kč	0 Kč	0 Kč
8_6	**EXTERNAL DRAINAGE**	**31 143 Kč**	**1 430 650 Kč**	**586 500 Kč**	**64 749 Kč**
8_6_1	Surface Water and Foul Water Drainage	0 Kč	43 750 Kč	0 Kč	0 Kč
8_6_2	Ancillary Drainage Systems	0 Kč	977 900 Kč	0 Kč	0 Kč
8_6_3	External Chemical, Toxic and Industrial Liquid Waste Drainage	0 Kč	234 000 Kč	0 Kč	0 Kč
8_6_4	Land Drainage	31 143 Kč	175 000 Kč	586 500 Kč	64 749 Kč
8_7	**EXTERNAL SERVICES**	**213 555 Kč**	**2 389 983 Kč**	**1 394 183 Kč**	**903 612 Kč**
8_7_1	Water Mains Supply	0 Kč	38 647 Kč	50 000 Kč	106 656 Kč
8_7_2	Electricity Mains Supply	0 Kč	57 600 Kč	111 759 Kč	106 500 Kč
8_7_3	External Transformation Devices	0 Kč	326 400 Kč	0 Kč	106 200 Kč
8_7_4	Electricity Distribution to External Plant and Equipment	0 Kč	756 250 Kč	0 Kč	105 000 Kč
8_7_5	Gas Mains Supply	0 Kč	624 000 Kč	534 478 Kč	0 Kč
8_7_6	Telecommunications and other Communication System Connections	213 555 Kč	251 520 Kč	334 554 Kč	400 440 Kč
8_7_7	External Fuel Storage and Piped Distribution Systems	0 Kč	0 Kč	0 Kč	0 Kč
8_7_8	External Security Systems	0 Kč	49 467 Kč	149 625 Kč	0 Kč
8_7_9	External/Street Lighting Systems	0 Kč	187 579 Kč	164 849 Kč	78 816 Kč
8_7_10	Local/District Heating Installation	0 Kč	98 520 Kč	48 918 Kč	0 Kč
8_7_11	Builder's Work In Connection With External Services	0 Kč	0 Kč	0 Kč	0 Kč
8_8	**MINOR BUILDING WORKS AND ANCILLARY BUILDINGS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
8_8_1	Minor Building Works	0 Kč	0 Kč	0 Kč	0 Kč
8_8_2	Ancillary Buildings and Structures	0 Kč	0 Kč	0 Kč	0 Kč
8_8_3	Underpinning to External Site Boundary Walls	0 Kč	0 Kč	0 Kč	0 Kč
9_1	**EMPLOYER'S REQUIREMENTS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
9_1_1	Site Accommodation	0 Kč	0 Kč	0 Kč	0 Kč
9_1_2	Site Records	0 Kč	0 Kč	0 Kč	0 Kč
9_1_3	Completion and Post Completion Requirements	0 Kč	0 Kč	0 Kč	0 Kč
9_2	**MAIN CONTRACTOR'S COST ITEMS**	**26 940 518 Kč**	**3 685 000 Kč**	**6 135 141 Kč**	**4 029 555 Kč**
9_2_1	Management and Staff	0 Kč	0 Kč	0 Kč	0 Kč
9_2_2	Site Establishment	404 155 Kč	450 000 Kč	875 608 Kč	583 000 Kč
9_2_3	Temporary Services	20 910 586 Kč	2 350 000 Kč	3 456 678 Kč	2 282 250 Kč
9_2_4	Security	0 Kč	0 Kč	0 Kč	0 Kč
9_2_5	Safety and Environmental Protection	5 311 434 Kč	535 000 Kč	1 238 865 Kč	787 505 Kč
9_2_6	Control and Protection	0 Kč	0 Kč	0 Kč	0 Kč
9_2_7	Mechanical Plant	314 343 Kč	350 000 Kč	563 990 Kč	376 800 Kč
9_2_8	Temporary Works	0 Kč	0 Kč	0 Kč	0 Kč
9_2_9	Site Records	0 Kč	0 Kč	0 Kč	0 Kč
9_2_10	Completion and Post Completion Requirements	0 Kč	0 Kč	0 Kč	0 Kč
9_2_11	Cleaning	0 Kč	0 Kč	0 Kč	0 Kč
9_2_12	Fees and Charges	0 Kč	0 Kč	0 Kč	0 Kč
9_2_13	Site Services	0 Kč	0 Kč	0 Kč	0 Kč
9_2_14	Insurance Bonds, Guarantees and Warranties	0 Kč	0 Kč	0 Kč	0 Kč
10_1	**MAIN CONTRACTOR'S OVERHEADS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
10_1_1	Main Contractor's Overheads	0 Kč	0 Kč	0 Kč	0 Kč
10_2	**MAIN CONTRACTOR'S PROFITS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
10_2_1	Main Contractor's Profits	0 Kč	0 Kč	0 Kč	0 Kč
11_1	**CONSULTANT'S FEES**	**516 090 Kč**	**1 081 434 Kč**	**823 412 Kč**	**684 792 Kč**
11_1_1	Project/Design Team Consultan's Fees	355 925 Kč	311 434 Kč	674 009 Kč	453 789 Kč
11_1_2	Other Consultan's Fees	160 166 Kč	770 000 Kč	149 403 Kč	231 003 Kč
11_1_3	Site Investigation Fees	0 Kč	0 Kč	0 Kč	0 Kč
11_1_4	Specialist Support Consultan's Fees	0 Kč	0 Kč	0 Kč	0 Kč
11_2	**MAIN CONTRACTOR'S PRE-CONSTRUCTION FEES**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
11_2_1	Management and Staff	0 Kč	0 Kč	0 Kč	0 Kč
11_2_2	Specialist Support Services Fees	0 Kč	0 Kč	0 Kč	0 Kč
11_2_3	Temporary Accomodation Services and Facilities Charges	0 Kč	0 Kč	0 Kč	0 Kč

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11_3	**MAIN CONTRACTOR'S DESIGN FEES**	**0 Kč**	**225 000 Kč**	**0 Kč**	**197 988 Kč**
11_3_1	Main Contractor's Design Fees on a Design and Build Contract		150 000 Kč		128 745 Kč
11_3_2	Main Contractor's Design and Project Management Fees on a Contractor Lead Framework and The Like		75 000 Kč		69 243 Kč
12_1	**OTHER DEVELOPMENT/PROJECT COSTS**	**0 Kč**	**0 Kč**	**1 249 574 Kč**	**0 Kč**
12_1_1	Land Acquisition Costs	0 Kč	0 Kč	0 Kč	0 Kč
12_1_2	Employer Finance Costs	0 Kč	0 Kč	0 Kč	0 Kč
12_1_3	Fees	0 Kč	0 Kč	0 Kč	0 Kč
12_1_4	Charges	0 Kč	0 Kč	0 Kč	0 Kč
12_1_5	Planning Contributions	0 Kč	0 Kč	0 Kč	0 Kč
12_1_6	Insurances	0 Kč	0 Kč	0 Kč	0 Kč
12_1_7	Archaeological Fieldworks	0 Kč	0 Kč	0 Kč	0 Kč
12_1_8	Other Specialist Fieldworks	0 Kč	0 Kč	1 249 574 Kč	0 Kč
12_1_9	Decanting and Relocation Costs	0 Kč	0 Kč	0 Kč	0 Kč
12_1_10	Fittings, Furnishings and Equipment	0 Kč	0 Kč	0 Kč	0 Kč
12_1_11	Tenant's Costs/Contributions	0 Kč	0 Kč	0 Kč	0 Kč
12_1_12	Marketing Costs	0 Kč	0 Kč	0 Kč	0 Kč
12_1_13	Other Employer Costs	0 Kč	0 Kč	0 Kč	0 Kč
13_1	**DESIGN DEVELOPMENT RISKS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
13_1_1	Design Development Risks	0 Kč	0 Kč	0 Kč	0 Kč
13_2	**CONSTRUCTION RISKS**	**0 Kč**	**0 Kč**	**0 Kč**	**0 Kč**
13_2_1	Construction Risks	0 Kč	0 Kč	0 Kč	0 Kč
13_3	**EMPLOYER CHANGE RISKS**	**4 271 098 Kč**	**480 000 Kč**	**0 Kč**	**480 000 Kč**
13_3_1	Employer Change Risks	4 271 098 Kč	480 000 Kč	0 Kč	480 000 Kč
13_4	**EMPLOYER OTHER RISKS**	**4 360 080 Kč**	**490 000 Kč**	**0 Kč**	**490 000 Kč**
13_4_1	Employer Other Risks	4 360 080 Kč	490 000 Kč	0 Kč	490 000 Kč
	TOTAL FOR BUILDING	**51 351 050 Kč**	**22 948 317 Kč**	**158 909 476 Kč**	**19 579 015 Kč**